

# The Geographic Distribution of Physicians Revisited

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**Context.** While there is debate over whether the U.S. is training too many physicians, many seem to agree that physicians are geographically maldistributed, with too few in rural areas.

**Objective.** Official definitions of shortage areas assume the market for physician services is based on county boundaries. We wished to ascertain how the picture of a possible shortage changes using alternative measures of geographic access. We measure geographic access by the number of full-time equivalent physicians serving a community divided by the expected number of patients (possibly both from within the community and outside) receiving care from those physicians. Moreover, we wished to determine how the geographic distribution of physicians had changed since previous studies, in light of the large increase in physician numbers.

**Design.** Cross-sectional data analyses of alternative measures of geographic access to physicians in 23 states with low physician–population ratios.

**Results.** Between 1979 and 1999, the number of physicians doubled in the sample states. Although most specialties experienced greater diffusion everywhere, smaller specialties had not yet diffused to the smallest towns. Multiple measures of geographic access, including physician-to-population ratios, average distance traveled to the nearest physician, and projected average caseload per physician, confirm that residents of metropolitan areas have better geographic access to physicians. Physician-to-population ratios exhibit the largest degree of geographic disparity, but ratios in rural counties adjacent to metropolitan areas are smaller than in those not adjacent to metropolitan areas. Distance-traveled and caseload models that allow patients to cross county lines show less disparity and indicate that residents of isolated rural counties have less access than those living in counties adjacent to metropolitan areas.

**Conclusion.** Geographic access to physicians has continued to improve over the past two decades, although some smaller specialties have not diffused to the most rural areas. While substantial variation in the supply of physicians across communities remains, current measures of geographic access to physicians overstate the extent of maldistribution and yield an incorrect ranking of areas according to geographic accessibility of physicians.

**Key Words.** Rural, geographic access, physician supply, workforce

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While views on the adequacy of the national physician workforce vary widely and fluctuate over time (Council on Graduate Medical Education [COGME] 1998; Cooper et al. 2002; Grumbach 2002a,b; Weiner 2002; Blumenthal 2004) most seem to agree that physicians are geographically maldistributed, with too few in rural areas. The COGME, for example, concluded that:

Geographic maldistribution of health care providers and service is one of the most persistent characteristics of the American health care system. Even as an over-supply of some physician specialties is apparent in many urban health care service areas across the country, many inner city and rural communities still struggle to attract an adequate number of health professionals to provide high-quality care to local people. This is the central paradox of the American health care system: shortages amid surplus (COGME 1998).

Government policies to increase the diffusion of physicians across underserved areas have been in place for decades and continue to evolve. Most recently, the Medicare Prescription Drug, Improvement, and Modernization Act of 2003 increased and expanded fee enhancements for physicians who provide services to enrollees in underserved areas. Medicare has included such additional payments for rural physicians since 1987, when Congress enacted the Medicare Payment Incentive Program. Similarly, designated Rural Health Clinics have historically been eligible for cost-based reimbursement under Medicare and Medicaid. The federal government also reinforces the health workforce directly in underserved areas through the National Health Services Corps and a wide variety of grant-making programs operated through the Health Resources and Services Administration. Medical schools have attempted to address health workforce shortages by recruiting and training individuals committed to practice in underserved areas (Adkins et al. 1987; Brazeau, Potts, and Hickner 1990; Rabinowitz et al. 1999).

Despite the wide array of policies and programs to address the issue, some reports have suggested that undersupply of primary care physicians (PCPs) is worsening in rural areas (Institute of Medicine 1996; Ricketts, Hart, and Pirani 2000). Physician-to-population ratios calculated at the county level

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are commonly relied upon as indicators of such worsening and are used in part to target government programs, including the subsidy enacted as part of the recent Medicare legislation. A number of published analyses, however, have suggested that this measure of disparity is misleading as an indicator of access because it assumes that residents only seek care in their own county, contrary to patient origin studies (Kleinman and Makuc 1983; Newhouse 1990). While the potential importance of patient travel to providers in adjacent areas is considered informally in designating underserved areas for the purpose of Federal policy, no systematic method has been proposed to incorporate such considerations into access measures.

There is an extensive literature that deals with modeling the diffusion of physicians and other health care resources across geographic areas and measures of geographic accessibility of physician services (Knox 1979; Joseph and Bantock 1982; Wing and Reynolds 1988; Kwan and Weber 2003; Guagliardo 2004). Several recent reviews synthesize current findings and methods in the context of a literature that dates to the nineteenth century (Kwan and Weber 2003; Guagliardo 2004). Both reviews concur as to the deficits of both provider-to-population ratios and distance models (also known as travel impedance models) for ascertaining spatial availability of physician services. The major criticism of these approaches relates to their failure to portray accurately the set of accessible physicians from the individual's point of view and to weigh each in proportion to their availability along the geospatial (and temporal) continuum.

Substantial progress to this end has been made using gravity models, which quantify accessibility as the weighted sum of physician resources within a given radius, with the weights given by a distance decay function (see, *inter alia*, Knox 1979). The more sophisticated versions of the gravity model also account for differences in patient demand facing each physician (Joseph and Bantock 1982). More recently, investigators at the University of New Mexico, Division of Government Research have been working on a "compound" gravity model, which accounts for the spatial distribution of potential patients and physicians at the zip-code level and derives an implied population-to-physician ratio (New Mexico Health Policy Commission 2004).

We note as well that there is a growing literature that goes well beyond the methods applied here to account for not just geospatial but temporal patterns of accessibility, particularly in urban areas. These efforts take advantage of sophisticated Geographic Information System capabilities to model with much greater precision the location of physicians and populations, as well as features such as roads and transportation options (Kwan et al. 2003).

Related issues have also been explored in the context of an effort to establish more realistic market area definitions for pediatric and primary care using insurance billing data to approximate patient travel patterns (Goodman et al. 2003; Guagliardo et al. 2004). These service areas are defined to include the plurality of providers used by residents and thus represent more rational markets than geopolitical units such as counties. While service areas represent a more logical locus of measurement and intervention for primary care workforce issues than counties, they do not greatly improve measures of access as a substantial share of care received by residents is obtained outside of the service area (roughly one-third, based on the studies).

To shed further light on disparities in geographic access to physicians, we updated earlier research to see how the distribution of physicians has changed in light of the large increase in overall supply. In a new analysis, we measure geographic access by estimating caseloads of physicians serving communities across the urban-rural spectrum, and we compare simulated PCP caseloads with thresholds established for designating Health Professional Shortage Areas (HPSAs). Our caseload analysis, which is akin to the compound gravity model described above, allows for explicit modeling of patient preferences with regard to travel distance to a physician and takes into account the availability of nearby alternatives in measuring access to care at the population level.

## METHODS

### *Sources of Data*

We ascertained the location of physicians in 1999 using self-reported address information from the American Medical Association (AMA) Physician Masterfile (Medical Marketing Service 1999). When possible, we used office zip code to locate physicians for the study; for approximately 20 percent of physicians only a home address was provided,<sup>1</sup> with higher rates in nonmetropolitan areas than metropolitan areas (25 versus 18 percent). To compare location patterns in 1999 with those of 1979, we used data for the 23 states that had been studied earlier (Newhouse et al. 1982a, b, c). Those states, located in four regions of the country, had below-average physician-population ratios in the 1970s and all but two still do now (American Medical Association 2001). They contain approximately half of the nonmetropolitan population of the U.S. as of 2000.

From the U.S. Census we obtained data on the population of zip-code areas, towns, counties, and Metropolitan Statistical Areas (MSAs) in those states (U.S. Census Bureau 2002). For the analysis of the availability of physicians by town size, we followed the earlier work (Newhouse et al. 1982a, b, c) in treating all cities and towns within an MSA as one city. Thus, a town of 10,000 in an MSA of 500,000 is grouped with our largest town-size category. In the analysis of both the 1979 and 1999 data, we used the same 1970 geographic definitions of metropolitan areas. In other words, we continued to classify counties that had become part of a metropolitan area after 1970 as nonmetropolitan, so that a town of 10,000 in such a county would still be classified as a town of 10,000. Using 1970 MSA definitions is a generally conservative approach because we exclude gains of measured access that resulted simply from small towns being consumed by MSAs. Although the geographic definition of an MSA was fixed, towns were classified using their current year population. Towns with populations below 2,500 were excluded from the analysis of location of physicians by size of town, but were included in all other analyses.

Analyses of distance to the nearest physician and primary care caseloads use the zip code as the unit of analysis except when we compare our results with county population-to-physician ratios. To compute the distance between physicians' offices and zip-code areas of the population, we obtained the latitude and longitude of the population centroid of each U.S. five-digit zip code in 2000 from ZipInfo.com, a private geographic information company. Conceptually, our goal is to measure the availability of physician services from the point of view of each resident and then summarize those individual access measures across different types of communities. Zip-code centroids are a convenient but imperfect proxy for actual population locations because everyone in a zip-code area does not live at the centroid. We therefore conducted sensitivity tests of our results for a single state (Alabama) using street address coordinates for physicians and census block locations for patients.

From the U.S. Department of Agriculture (USDA), we obtained the rural-urban continuum code for each county in the United States (Butler and Beale 1994). This system (Table 1) classifies all U.S. counties by degree of urbanization and proximity to a metropolitan area and improves on the simple metropolitan-nonmetropolitan distinction used previously. These codes are based on the June 1993 Census definition of MSAs.

We examined 17 categories of PCPs and specialists. Specialty designations were reported by the physicians and coded according to the standard AMA classification scheme. Given the proliferation of new subspecialties, we

Table 1: Rural–Urban Continuum Codes

<i>Code</i>	<i>Definition</i>
0	Central counties of metropolitan areas of 1 million population or more
1	Fringe counties of metropolitan areas of 1 million population or more
2	Counties in metropolitan areas of 250,000 to 1 million population
3	Counties in metropolitan areas of fewer than 250,000 population
4	Urban population of 20,000 or more, adjacent to a metropolitan area
5	Urban population of 20,000 or more, not adjacent to a metropolitan area
6	Urban population of 2,500 to 19,999, adjacent to a metropolitan area
7	Urban population of 2,500 to 19,999, not adjacent to a metropolitan area
8	Completely rural or fewer than 2,500 urban population, adjacent to a metropolitan area
9	Completely rural or fewer than 2,500 urban population, not adjacent to a metropolitan area

Rural–urban continuum codes are based on June 1993 Metropolitan Statistical Area designations from the U.S. Census.

made every effort to make the categories comparable over time. Following the earlier work (Newhouse et al. 1982c), we grouped specialties into four larger groups. These four groups are defined based on their overall numbers in 1979, which in turn correspond to predictions about diffusion.

Our measures of geographic access to physicians take into account information on type of practice from the AMA Masterfile. First, physicians who reported that they work 20 hours or less (including retired and semiretired physicians), residents, and those whose principal activity was administration, medical research, or other nonclinical responsibility were excluded from the analysis. Sensitivity analyses suggest that this exclusion has no qualitative impact on our results. We included those physicians who reported that their principal activity is teaching but counted them as only 0.5 of a full-time equivalent (FTE). Most medical schools are located in larger metropolitan areas, so that any error in this fraction would principally affect the measured access of individuals within those areas, leaving our main conclusions unaffected. Because we were interested in the location choices of private physicians, we also excluded federal physicians. Finally, in our data a physician could report one or two specialties; if the physician reported two, we counted the first specialty as 0.6 FTE and the second as 0.4 FTE in our analysis of caseloads. Sensitivity analysis showed that altering the weights with which we count FTEs by specialty has very little impact on our measures of geographic access to physicians, because the majority of physicians in our data report only one specialty and this percentage is relatively invariant along the rural–urban continuum.

*Method of Analysis*

We conducted three types of analyses of physician location in our 23-state sample. First, we examined the percentage of communities (MSAs or towns not in MSAs) with any specialist in each of the 17 specialty groups, in addition to an umbrella category that includes all physicians. For comparative purposes, we display our town-level estimates with those reported earlier for 1979 (Newhouse et al. 1982c).

The foregoing analysis tells us only whether at least one practitioner is present in a town, but says nothing directly about the adequacy of supply. We computed the average number of FTE physicians in each specialty per 100,000 persons in counties grouped according to the USDA's rural-urban continuum codes. This analysis allows us to test whether residents who live in counties adjacent to metropolitan areas face ratios similar to or different from residents in nonadjacent counties of similar size.

Physician-to-patient ratios by county are an imprecise measure of access because some patients might be able to use a nearby physician in an adjacent county, while others might have to travel a long distance to see a physician, even in the same county. Therefore, we calculated the distance from each zip-code centroid (representing the resident population location) to the closest physician of each type and report population-weighted average distances to a physician for the residents of each rural-urban continuum category. Distances were calculated from the latitude and longitude of the population and doctor zip-code centroids using the Haversine formula (Sinnott 1984).

Finally, even if there is a nearby physician, that physician may be swamped with patients. We therefore estimated caseloads of PCPs (defined as family practitioners [FPs], general practitioners [GPs], internists, pediatricians, and obstetricians-gynecologists) in each rural-urban continuum category. We limited the analysis to PCPs because nonmetropolitan residents are expected to travel to metropolitan areas for some secondary and tertiary care. We lacked data on actual PCP caseloads, defined as the expected number of patients using each PCP. To estimate caseloads, we used distances from patients to physicians and we made a range of different assumptions about travel pattern to allocate patients to physicians. The four alternative assumptions are: (1) patients distribute themselves over PCPs who practice in their own county, the implicit assumption of official measures using PCP/population ratios; (2) patients always go to the nearest PCP even if that PCP is in another county or other doctors are located a few miles further away; and (3) patients choose a PCP with a probability that is an exponentially declining function of distance

traveled to the PCP. The exponent was chosen so that the mean distance would be either 5 or 10 miles if physicians and patients were evenly distributed across the landscape. Specifically, we assumed that the probability a patient will seek care from a given physician who is distance  $d$  away is proportional to  $e^{-\lambda d}$ , where  $\lambda$  is alternatively 0.4 (mean distance of 5 miles) or 0.2 (mean distance of 10 miles). Patients at each zip code of residence are allocated to surrounding doctors in proportion to that value, up to a maximum of 25 miles. Thus, patients may choose to bypass the nearest PCP, but are more likely to seek care from closer-by physicians. For zip-code locations without a PCP within 25 miles (about 7 percent of the zip codes, containing 1 percent of the population) we assigned the population to the nearest PCP location. If, contrary to our assumption, patients are willing to travel further than 25 miles, patient loads should be more equal across physicians than we calculate.

Under each of these alternative assumptions, we allocated patients to PCPs and estimate the caseload of each PCP. Physician-level caseload estimates were combined for all the PCPs within 25 miles of each patient's zip-code location in proportion to physicians' expected share of that zip code's population and then averaged using zip-code population weights over all the zip codes within a rural-urban continuum category. Caseload averages thus reflect not only the total number of physicians but also the unevenness of their distribution across population areas.

When we constrain travel, for example by assuming that patients go to the nearest doctor, we raise population-weighted average caseloads relative to methods that allow greater patient dispersion. For example, if each of two adjacent zip codes has a population of 1,000, but one has a single PCP and the other has five, average caseloads will be higher if each person is assigned to the nearest PCP ( $600 = 0.5(1,000) + 0.5(1,000/5)$ ) than if some patients from the zip code with the single PCP travel to the other zip code for care ( $333 = 2,000/6$  if caseloads fully equalize).

We compared mean values of our measures of geographic access among rural-urban continuum categories. Significance tests for these pairwise comparisons were conducted using standard  $t$ -tests with the county as the unit of analysis for Table 3 and for the first row of Table 5. The zip-code area was the unit of analysis for Table 4 and for the last three rows of Table 5. We used a threshold of  $p < .05$  to report statistical significance. Because patterns of geographic access have been shown to vary by region of the country, we also describe these patterns in our PCP caseload results.

Finally, we compared all of our simulated PCP caseloads with the standard used by the federal government to identify HPSAs. An HPSA is

typically defined by “a load exceeding 3,500 patients per primary care doctor over a suitably defined area in the absence of exacerbating circumstances or an ample supply of doctors in an immediately adjacent area” (Federal Register 1993). Sometimes an area may qualify as an HPSA with a PCP caseload of only 3,000, for example when language barriers restrict access. Because these exceptions are not uniformly interpreted and are difficult to model, we use an average PCP caseload of 3,500 or greater as a measure of HPSA eligibility. We used the county as the unit of analysis for tractability. HPSAs are not necessarily designated at the county level, and especially in urban areas may be assigned to smaller territorial units such as neighborhoods, but about half of nonmetropolitan HPSAs are whole counties. In sum, we compared the average caseloads of physicians serving the population of each county against the HPSA threshold and report the share of the population living in counties exceeding the shortage standard.

## RESULTS

### *Location in 1999 Compared with 1979*

Table 2 displays the share of communities with nonfederal physician specialty services of each type, ordered by the total supply of FTE physicians in our 23-state sample in 1979. During the 20 years since the previous studies, the number of physicians in the sample states has more than doubled. These results are consistent with numerous national studies that have been published in the intervening period (Council on Graduate Medical Education 1998). Nearly all specialties saw substantial growth, with general surgery the exception. The number of pediatricians and plastic surgeons grew at disproportionately high rates, while some specialties such as urology and radiology showed more modest gains.

Reflecting the disproportionately rural nature of our sample of states, GPs and FPs outnumber internists, although this is not the case nationally. In 1999, 91 percent of towns with 2,500–5,000 population in the 23 states had a GP or FP, an increase of 5 percentage points over 1979. With the exception of general surgery, whose numbers fell, and radiology, each specialty listed in Group 2 showed striking gains in certain town size categories. The percentage of towns of 5,000 to 10,000 with an internist grew from 52 to 69 percent and with a pediatrician grew from 25 to 43 percent. The proportion of towns of 20,000 to 30,000 with a psychiatrist grew from 59 to 85 percent.

Table 2: Percentage of Communities with Nonfederal Physician Specialty Services in 1979 and 1999

Specialty	No. of FTE Physicians	Population in Thousands						
		2.5-5	5-10	10-20	20-30	30-50	50-200	200+
Group 1								
General and family practice								
1979	11,869	86	96	99	100	100	100	100
1999	21,919	91	96	99	100	100	100	100
Group 2								
Internal medicine								
1979	9,467	23	52	84	97	100	100	100
1999	20,654	41	69	93	98	100	100	100
General surgery								
1979	6,071	44	77	96	100	100	100	100
1999	5,275	38	63	88	97	98	100	100
Obstetrics-gynecology								
1979	3,978	15	35	77	97	100	100	100
1999	7,092	15	41	82	98	100	100	100
Psychiatry								
1979	3,203	9	17	40	59	96	100	100
1999	6,155	9	26	53	85	98	100	100
Pediatrics								
1979	3,429	12	25	68	92	100	100	100
1999	9,356	16	43	84	97	100	100	100
Radiology								
1979	3,042	9	30	73	97	100	100	100
1999	4,909	13	36	68	92	98	100	100
Group 3								
Anesthesiology								
1979	2,303	11	19	40	83	100	100	100
1999	5,914	7	20	64	83	100	100	100
Orthopedic surgery								
1979	2,409	7	17	47	88	100	100	100
1999	3,927	7	28	69	94	98	100	100
Ophthalmology								
1979	2,147	4	14	62	89	100	100	100
1999	3,328	3	18	60	89	98	100	100
Pathology								
1979	1,840	4	15	50	85	95	100	100
1999	2,747	4	13	49	74	89	100	100
Urology								
1979	1,340	2	10	47	89	100	100	100
1999	1,879	2	13	57	78	95	100	100
Otolaryngology								
1979	1,127	2	6	29	79	98	98	100
1999	1,685	1	10	46	74	93	100	100

*continued*

Table 2: *Continued*

<i>Specialty</i>	<i>No. of FTE Physicians</i>	<i>Population in Thousands</i>						
		<i>2.5-5</i>	<i>5-10</i>	<i>10-20</i>	<i>20-30</i>	<i>30-50</i>	<i>50-200</i>	<i>200+</i>
Dermatology								
1979	795	1	3	15	59	96	98	100
1999	1,475	2	7	33	57	96	100	100
Group 4								
Neurology								
1979	724	1	4	13	24	70	98	100
1999	1,901	1	7	28	63	88	98	100
Neurosurgery								
1979	523	0	1	2	18	56	88	100
1999	936	0	1	9	23	52	90	100
Plastic surgery								
1979	430	1	1	8	20	46	83	100
1999	1,020	1	3	18	37	73	96	100
Any physician								
1979	58,911	92	98	100	100	100	100	100
1999	119,109	94	97	99	100	100	100	100
No. of towns								
1979		644	379	206	66	57	40	34
1999		582	413	235	65	56	52	41

*Source:* Authors' calculations using AMA Masterfile data, U.S. Census data, and Newhouse et al. (1982c). The states included in the sample are: AL, AK, CO, GA, IA, ID, KA, LA, ME, MN, MO, MS, MT, ND, NE, NH, OK, SD, TN, UT, VT, WI, and WY.

FTE, full-time equivalent; AMA, American Medical Association.

Among the smaller specialties shown in Group 3, pathologists, urologists, ophthalmologists, and otolaryngologists were more unevenly diffused. The proportion of towns of size 10,000–20,000 with all types of Group 3 specialists except pathologists grew substantially, but with a few exceptions there was little growth among other town-size categories. In the smallest towns, there was a contraction in the proportion with anesthesiologists, ophthalmologists, and otolaryngologists. The three small specialties shown in Group 4 are the least diffused; still, the proportion of towns of 20,000 to 30,000 with a neurologist grew from 24 to 63 percent, and the proportion of towns of 30,000–50,000 with a plastic surgeon grew from 46 to 73 percent.

#### *Physicians per 100,000 Population by County Type*

In 1999, GP/FPs were distributed relative to the population with little variation across different types of counties (Table 3). Physician-to-population ratios

Table 3: FTE Physicians per 100,000 Population by Rural–Urban Continuum Code

<i>Specialty</i>	<i>Rural–Urban Continuum Code</i>									
	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
Group 1										
General and family practice	26.8	22.3	31.6	35.6	32.5	34.7	34.7	38.7	25.0	35.5
Group 2										
Internal medicine	45.2	13.0	37.3	38.6	25.7	30.4	11.7	14.9	5.7	7.0
General surgery	8.2	4.0	8.6	9.1	7.5	10.4	5.8	7.6	1.9	3.5
Obstetrics–gynecology	14.8	5.3	12.6	11.5	9.8	12.9	4.5	5.8	0.8	1.2
Psychiatry	11.6	2.0	8.5	9.7	6.1	8.4	2.6	3.6	1.0	1.3
Pediatrics	22.4	6.9	17.5	14.8	10.5	12.1	4.4	5.5	1.3	2.0
Radiology	8.7	2.4	8.4	8.9	6.0	8.5	2.8	4.2	0.8	1.0
Group 3										
Anesthesiology	12.9	3.2	11.8	11.6	6.4	9.5	2.1	2.9	1.2	0.7
Orthopedic surgery	7.2	2.2	7.0	7.7	5.6	8.6	2.2	4.1	0.5	0.5
Ophthalmology	6.6	1.3	5.9	6.4	5.0	7.2	1.7	2.6	0.1	0.3
Pathology	4.4	0.9	4.3	4.8	2.6	4.6	0.9	1.7	0.4	0.2
Urology	3.2	0.9	3.3	4.2	2.9	4.4	0.9	1.6	0.1	0.2
Otolaryngology	3.1	1.0	3.2	3.5	2.6	3.9	0.6	1.0	0.1	0.2
Dermatology	3.3	0.7	2.6	3.2	1.9	2.7	0.3	0.8	0.0	0.0
Group 4										
Neurology	3.9	0.7	3.2	4.1	2.2	3.0	0.3	0.8	0.1	0.1
Neurosurgery	1.8	0.2	2.1	2.3	0.8	2.1	0.1	0.1	0.0	0.0
Plastic surgery	2.2	0.3	2.0	1.5	0.8	1.2	0.1	0.2	0.0	0.1
<i>All physicians</i>	212.9	75.1	188.3	185.9	142.7	173.4	83.6	107.8	44.1	60.8

*Source:* Authors' calculations using AMA Masterfile and U.S. Census data. See note to Table 2 for states included.

FTE, full-time equivalent; AMA, American Medical Association.

varied much more among all the other specialties, resulting in average total physician-to-population ratios that varied sixfold across the 10 continuum categories. With the exception of GPs/FPs, metropolitan counties (rural–urban continuum codes 0, 1, 2, or 3) had the highest physician-to-population ratios for all specialties. Fringe counties of metropolitan areas of 1,000,000 or more (Group 1), however, have markedly fewer physicians of each specialty than the smaller metropolitan areas ( $p < .01$ ).

Within nonmetropolitan counties, however, ratios were systematically related to adjacency to a metropolitan area. Comparing categories 4 and 5, nonmetropolitan counties with urban populations of 20,000 or more that are adjacent and not adjacent, respectively, to a metropolitan area, the adjacent counties in every instance have a *smaller* physician–population ratio.

Differences are statistically significant ( $p < .05$ ) for 11 of 17 specialties (general surgery, obstetrics–gynecology, radiology, anesthesiology, orthopedic surgery, ophthalmology, pathology, urology, otolaryngology, dermatology, and neurosurgery). For county groups 6 and 7, the differences are in the same direction and are all significant ( $p < .05$ ) save for psychiatry, neurosurgery, and plastic surgery for which the number of physicians in both county groups is small. Finally, the pattern is similar for county groups 8 and 9, although the only significant differences are for GPs/FPs, general surgeons, and ophthalmologists ( $p < .05$ ).

#### *Distance to Nearest Physician*

On average, patients were not very far from a physician (last row, Table 4). Even in the most remote category of counties, with an urban population less than 2,500 and not adjacent to a metropolitan area, the mean distance to the nearest physician of any type was less than 5 miles. For somewhat larger places, distances were considerably shorter. The distribution of distances within an urban–rural code category was skewed, especially in the more rural areas. For example, the median and 90th percentiles of distance to the nearest physician of any type in urban–rural code category 9 were zero (i.e., there was a doctor in the same zip code) and 14 miles, respectively (data not shown). These are straight-line distances; earlier work found that average highway distance was about 25 percent greater, and that this difference was very consistent across urban and rural areas (Williams et al. 1983).

For determining excessive distance, the HPSA methodology uses a 30 minute driving time, which it approximates as a distance of 20 miles under normal road conditions. Using this measure, the average driving time to almost all specialists in county groups 4 and 5 is less than half an hour. The criterion is also generally satisfied for the larger specialties (Group 2) in county groups 6 and 7, and for GPs, FPs, internists, and general surgeons in the most rural counties (county groups 8 and 9). Residents of nonmetropolitan counties that are adjacent to a metropolitan area generally live closer to a given specialist than residents in counties that are not adjacent to a metropolitan area despite the greater number of physicians per person in the latter counties.

#### *PCP Caseloads*

Table 5 presents average PCP caseloads under alternative assumptions about how patients allocate themselves to nearby physicians. When we restrict patients to PCPs who practice within their counties of residence, we find that

Table 4: Distance in Miles to Nearest Physician, by Specialty and Rural–Urban Continuum Code

<i>Specialty</i>	<i>Rural–Urban Continuum Code</i>									
	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
Group 1										
General and family practice	0.2	1.0	0.6	0.9	1.1	1.2	2.2	2.0	4.2	5.5
Group 2										
Internal medicine	0.3	2.4	1.3	1.7	2.5	2.4	5.8	6.6	11.8	16.8
General surgery	1.2	3.8	2.9	3.3	2.9	2.9	6.7	6.8	15.5	18.1
Obstetrics–gynecology	1.1	4.2	3.0	3.6	3.5	2.7	11.4	13.0	18.7	27.2
Psychiatry	1.2	6.9	3.1	3.2	4.9	5.4	15.6	21.4	20.7	32.2
Pediatrics	0.6	3.8	2.1	2.7	3.7	3.0	10.8	12.9	18.3	25.5
Radiology	1.8	6.3	3.6	4.1	3.9	3.6	13.1	14.2	20.5	27.0
Group 3										
Anesthesiology	1.2	6.6	2.9	3.4	4.7	6.0	16.5	21.0	21.3	34.3
Orthopedic surgery	2.0	6.0	4.0	4.4	4.0	3.9	15.3	15.9	22.0	30.5
Ophthalmology	2.0	8.9	4.1	4.3	5.2	4.5	17.8	20.7	23.8	34.3
Pathology	2.4	11.4	4.5	5.2	9.1	7.0	19.4	24.6	23.7	37.7
Urology	3.3	10.4	5.2	5.4	6.1	5.3	19.8	23.8	25.2	37.0
Otolaryngology	2.7	9.6	5.0	6.1	6.9	4.9	21.8	27.6	26.5	39.1
Dermatology	2.3	10.8	5.4	5.5	8.1	13.7	23.6	31.8	27.5	43.6
Group 4										
Neurology	2.7	10.4	5.3	6.3	9.1	10.4	25.8	34.2	27.5	45.3
Neurosurgery	4.4	15.4	7.3	8.8	26.4	29.0	30.6	51.2	31.7	63.0
Plastic surgery	3.3	13.3	6.2	7.2	15.9	31.1	28.7	49.0	30.2	59.9
<i>Any physician</i>	0.1	0.6	0.4	0.6	0.8	0.9	1.8	1.7	3.3	4.7

*Source:* Authors' calculations using AMA Masterfile and U.S. Census data. See note to Table 2 for states included.

AMA, American Medical Association.

PCPs in central counties of large metropolitan areas have extremely low caseloads, while PCPs in fringe counties of the same size metropolitan areas appear to serve more than twice as many potential patients. This unequal pattern is replicated when we examine average caseloads for nonmetropolitan counties with equal-sized urban populations that are adjacent and not adjacent to metropolitan areas (e.g., group 4 versus group 5). That is, PCPs in nonmetropolitan counties adjacent to a metropolitan area appear to have higher caseloads than those in counties with the same size urban population not adjacent to a metropolitan area. Implied caseloads in the first row of the table range from a low of 1,029 (rural–urban code 0) to a high of 3,935 (rural–urban code 8).

The picture changes substantially, however, if we allow patients to cross county lines. Under the assumption that patients receive their care from the

Table 5: Average PCP Caseloads

<i>Travel Assumptions</i>	<i>Rural–Urban Continuum Code</i>									
	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
Consumers can only access PCPs in own county	1,029	2,297	1,339	1,233	1,439	1,245	2,213	1,846	3,935	2,959
Consumers choose closest PCP	2,798	4,304	3,268	2,940	3,199	2,516	3,097	2,343	4,338	3,293
Probability declines exponentially with distance: average distance = 5 miles	1,089	2,148	1,347	1,448	1,659	1,663	2,207	1,948	3,343	2,648
Probability declines exponentially with distance: average distance = 10 miles	1,013	1,461	1,129	1,257	1,475	1,472	1,774	1,775	2,266	2,093

*Source:* Authors' calculations using data from the AMA Masterfile and U.S. Census data. See note to Table 2 for states included.

PCP, Primary Care Physician; AMA, American Medical Association.

nearest PCP, caseloads are much higher than in the first row. Caseloads are reduced and made more equal when we assume that not all patients seek care from their nearest physician but instead they choose physicians with declining probability as a function of distance. In the model where the hypothetical average distance is 10 miles when patients and physicians are evenly distributed ( $\lambda = 0.2$ ), the range in patients per PCP physician is from 1,013 (rural–urban code 0) to 2,266 (rural–urban code 8). The estimated mean distance traveled is 6.0 miles (not shown) because patients are somewhat clustered and physicians locate in those clusters. Moreover, despite the lower physician–population ratios in counties adjacent to metropolitan areas noted above (Table 3), in this model caseloads of physicians located in those adjacent counties are virtually identical to those in the nonadjacent counties except in the smallest county size group. In these counties (rural–urban codes 8 and 9), the estimated caseload is 8 percent higher in counties not adjacent to metropolitan areas compared with counties adjacent to metropolitan areas.

The average physician's caseload, however, may mask a subset of PCPs with high caseloads. For that reason we calculated the percentage of the population in different county groups who were assigned to a PCP that treated more than 3,500 patients, analogous to the measure of a shortage area used by

Table 6:    Percent of Population Residing in a Potential HPSA\*

<i>Travel Assumptions</i>	<i>Rural–Urban Continuum Code</i>									
	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
Consumers can only access PCPs in own county	0.3	12.0	4.0	2.4	0.0	0.0	9.3	3.8	44.6	29.8
Consumers choose closest PCP	21.7	52.8	30.9	28.2	29.3	16.2	28.3	13.2	52.0	29.7
Probability declines exponentially with distance: average distance = 5 miles	0.0	3.9	1.7	1.4	1.7	4.1	8.7	5.5	30.0	19.0
Probability declines exponentially with distance: average distance = 10 miles	0.0	0.1	0.0	0.4	0.0	0.0	1.0	1.9	11.1	7.3

\*A potential HPSA is defined here as an average primary care caseload greater than 3,500 patients.  
*Source:* Authors’ calculations using data from the AMA Masterfile and U.S. Census data. See note to Table 2 for states included.  
AMA, American Medical Association; HPSA, health professional shortage area; PCP, primary care physician.

the federal government. The percentages of such patients differed markedly according to the assumption we made about how patients distributed themselves among physicians (Table 6). When we assumed that patients distributed themselves probabilistically across physicians and traveled an average of 10 miles, in all size groups except the two most rural, few patients were assigned to a physician with a caseload exceeding this threshold. Even in the two most rural groups, only 11 and 7 percent, respectively, of patients were assigned to such a busy physician.

Upon examination of caseloads by region, we found several notable patterns (data not shown). Across most measures, the South and West typically faced poorer geographic access than other regions, particularly in the most rural counties. In these same county categories, the Northeast region exhibited remarkably low caseloads by all measures.

*Sensitivity of Results to Use of Zip-Code Centroids to Measure Location*

Our method of calculating distance makes the unrealistic assumption that everyone lives at the population centroid of the zip code. To determine the

effect this assumption has on our results, we compared the zip-code-level results for a single state, Alabama, to more precise estimates using physician street address and Census block locations. These analyses suggest that using zip-code centroids to locate physicians and populations understates distances by about one-third and that the size of the understatement varies by type of community in terms of the rural-urban continuum. Generally, our distances were understated more for residents in rural counties not adjacent to a metropolitan area and for residents in smaller metropolitan counties, where the distance to a nearby physician is often zero by zip-code centroid but several miles by actual address. For the same reason, distance calculations for specialties that are less well diffused are subject to less error than those for PCPs. Our caseload measures, which use distance only in relative terms, are less sensitive to the level of geocoding than the raw distance calculations. We found that our caseload estimates were *overstated* by roughly 15–25 percent using zip-code centroids and that this bias was very similar for all types of areas except the most rural (rural-urban continuum codes 8 and 9), where the bias was 35–50 percent. Despite these biases, there were no qualitative differences in our findings when we examined the same set of results using more precise distance measures.

## DISCUSSION

Previous research demonstrated that the geographic diffusion of physicians in the U.S. is consistent with standard economic location theory, contrary to the assumption of market failure embodied in current federal policy, which provides additional incentives for rural practice and in other ways facilitates it (Newhouse et al. 1982b). The presumed market failure is that physicians will not be drawn to underserved areas because of their ability to induce demand in desirable locations. To the contrary, economic theory predicts that physicians of a given specialty will tend to locate so as to equalize their patient loads. Thus, as specialties expand, physicians locate both in previously unserved smaller communities, as well as in locations where their colleagues are already practicing. Nonetheless, in the smallest towns, with populations between 2,500 and 5,000, overall increases in most of the smaller specialties between 1979 and 1999 did not result in increased presence because physicians in those specialties were just reaching somewhat larger towns where they would have higher caseloads. The overall contraction among general surgeons in our 23 states reduced the propensity for towns in all size groups less than

50,000 to have a practicing general surgeon. As location theory predicts, the greatest proportional impact of this contraction was on the smallest towns.

All of our measures, physician-to-population ratios, distance traveled, and caseload per physician, confirm that residents of metropolitan areas generally have better geographic access to physicians than residents of nonmetropolitan areas. Nonetheless, our data suggest that the magnitude of geographic disparities is overstated by conventional measures. When we distributed patients so that they would travel on average 10 miles to a PCP but with a probability of using any single PCP that declines with distance, we estimate average caseloads across the 10 rural-urban categories of between 1,013 and 2,266 patients per PCP.

More importantly, when we assume that patients distribute themselves somewhat equally over nearby PCPs, our estimated physician caseloads show that very few patients are assigned to a physician with a caseload that exceeds the federal guidelines for defining shortage areas. Even in the most rural counties, those with no town with more than 2,500 persons, only 11 and 7 percent of patients were estimated to use physicians with such a high caseload. Furthermore, we assumed patients would not travel further than 25 miles to a PCP, but if some patients in those very rural counties do travel greater distances, that would further equalize physician caseloads.

Physician-to-population ratios defined by county give a misleading picture of physician supply. For example, inferring the adequacy of physician supply from these ratios, it would appear that fringe counties within a metropolitan area (county group 1) are substantially more deprived than many nonmetropolitan counties (county groups 4, 5, and 7). These findings are consistent with previous national analyses of physician location that have demonstrated that adjacency to a metropolitan area is associated with fewer physicians per capita practicing inside county lines (Council on Graduate Medical Education 1998). But this is misleading because patients cross county boundaries to seek care. Because care seeking is a function of distance from the physician, those who live in adjacent counties are more likely to seek care in the metropolitan area than those who live in nonadjacent counties (Phelps and Newhouse 1974). The lower ratios in the fringe metropolitan counties undoubtedly reflect the greater proclivity of persons living in such counties to seek care from physicians in the metropolitan county that includes the central city. Our analysis of the distance to the nearest physician of a given type and particularly of physician caseloads when patients are not restricted to their county of residence also shows the importance of accounting for the presence of physicians in nearby counties. Our results are especially important given

patient origin analyses showing that many rural residents do obtain care outside their county of residence (Kleinman and Makuc 1983).

Our findings should be interpreted in the light of several limitations. First, our results are for 23 states rather than for the entire country. Of these states, 21 have below average physician–population ratios, so geographic access in the country as a whole should be better than our results show. Moreover, our sample states differ somewhat from national patterns of physician supply. Notably, over the past two decades, the numbers of FPs, pediatricians, and radiologists increased much more in our sample states than nationally, while nationally the number of general surgeons grew modestly as compared with the contraction in our sample.

Second, we assume that patients choose a physician based on a hypothetical function of distance. Estimates of physician caseloads could be improved by using data on actual patterns of use, accounting for other factors such as physician quality, thereby creating a more realistic model of caseloads. Some estimates of decay functions have been made for specific areas and populations, but more systematic study with appropriate accounting for endogeneity is needed (Wing and Reynolds 1988).

Third, like most other physician workforce studies, we rely on the AMA Masterfile to establish the location and specialty of practicing physicians. Researchers working with specific regions and time periods have documented, variously, a net overcount and a net undercount of physicians in the AMA Masterfile (Cherkin and Lawrence 1977; Williams et al. 1983; Stamps and Boley Cruz 1994; Konrad et al. 2000; Ricketts, Hart, and Pirani 2000). If there is a net over(under)count, all of the measures of geographic access reported in the paper are over(under)stated, although the comparison across measures is unlikely to be affected. Other reported problems, including the validity of self-reported specialty and incorrect address information, will add noise to all of our estimates but should not result in bias. Despite its shortcomings, it is our observation that the AMA Masterfile is the most readily available source of information on physicians for national workforce policy making and thus will continue to be used to obtain estimates of geographic access to primary and specialty care. If this is the case, it may be warranted for the agencies that rely on these data to work with the vendor of the AMA Masterfile to improve data quality.

Our results are made imprecise by the use of zip codes to locate physicians and populations. As is well known, zip-code areas and centroids are not geographically or economically meaningful units. Moreover, there may be imprecision in the methods used to assign coordinates to each zip-code area. Thus, although our sensitivity analysis suggested that use of zip codes, rather

than street addresses and census blocks, does not alter the major findings of our caseload analysis, it would be preferable to employ more precise geocoding when implementing these measures for policy to ensure effective and equitable resource allocation. Finally, our results do not address the magnitude or distribution of cultural, language, financial, or other access problems. These findings are thus not germane to access problems of inner-city residents, which do not primarily derive from distance barriers.

In sum, our results suggest that geographic access to most types of physicians has continued to improve over the past two decades, as a result of market forces and a wide range of health resource policies that affect the overall supply of physicians and their distribution. Although substantial variation in the supply of physicians across communities remains, official measures of the adequacy of physician supply likely overstate these differences by not properly accounting for patient travel across political boundaries. In particular, our analyses of the distance to the nearest physician and our simulated PCP caseloads suggest that current measures of geographic access to physicians are misleading. Because geographic access is an important factor for implementing health workforce policy, for example, in the designation of HPSAs, more accurate measures of such access will improve resource allocation. Refined versions of the primary care caseload measures we present here and their extension to specialists might represent substantial progress in this direction.

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## NOTE

1. Many physicians in the sample provided both home and office addresses. Among these physicians roughly 55 percent reported home and office addresses in the same zip code.

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