

Research Article

Socioeconomic, Rural-Urban, and Racial Inequalities in US Cancer Mortality: Part I—All Cancers and Lung Cancer and Part II—Colorectal, Prostate, Breast, and Cervical Cancers

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We analyzed socioeconomic, rural-urban, and racial inequalities in US mortality from all cancers, lung, colorectal, prostate, breast, and cervical cancers. A deprivation index and rural-urban continuum were linked to the 2003–2007 county-level mortality data. Mortality rates and risk ratios were calculated for each socioeconomic, rural-urban, and racial group. Weighted linear regression yielded relative impacts of deprivation and rural-urban residence. Those in more deprived groups and rural areas had higher cancer mortality than more affluent and urban residents, with excess risk being marked for lung, colorectal, prostate, and cervical cancers. Deprivation and rural-urban continuum were independently related to cancer mortality, with deprivation showing stronger impacts. Socioeconomic inequalities existed for both whites and blacks, with blacks experiencing higher mortality from each cancer than whites within each deprivation group. Socioeconomic gradients in mortality were steeper in nonmetropolitan than in metropolitan areas. Mortality disparities may reflect inequalities in smoking and other cancer-risk factors, screening, and treatment.

1. Part I

1.1. Introduction. Monitoring socioeconomic, racial, and geographic disparities in health, disease, and mortality has been the focus of epidemiologic and public health research in the US ever since the launch of the first comprehensive national health initiative in health promotion and disease prevention in 1979 [1, 2]. Previous research has shown the dynamic nature of social disparities in cancer mortality as the association between socioeconomic status (SES) and mortality from major cancers has changed markedly during the past 5 decades [3–5]. For example, area socioeconomic patterns in US mortality from all cancers combined and lung cancer reversed between 1950 and 1998, with those in more deprived groups in the recent period experiencing higher mortality risks than their more affluent counterparts [3–5].

In the 1950s and 1960s, cancer mortality rates were substantially higher for those in more affluent groups [3, 4]. The reversal in patterns occurred largely as a result of faster increases in mortality among those in lower SES groups and faster and earlier reductions in mortality among higher SES groups [3–5].

The pattern of association between cancer mortality and SES, whether measured at the individual or area level, has been shown to vary for specific cancers [3–14]. Contemporary data indicate that higher SES is associated with lower rates of lung, stomach, cervical, esophageal, oropharyngeal, and liver cancer mortality and higher rates of breast cancer and melanoma [3–14]. The major behavioral determinants of cancer, such as smoking, diet, alcohol use, obesity, physical inactivity, reproductive behavior, occupational and environmental exposures, and cancer screening

are themselves substantially influenced by individual- and area-level socioeconomic factors [5, 15–18].

Analyzing socioeconomic, rural-urban, and racial patterns in cancer mortality is important because it allows us to quantify cancer-related health disparities between the least and most advantaged social groups and to identify areas or population groups that are at greatest risk of cancer mortality and who may therefore benefit from focused social and medical interventions [5]. Such an analysis is also useful for tracking progress toward reducing health disparities in cancer as recent estimates of cancer mortality disparities can be compared with those that prevailed in the previous decades. Comparison of cancer mortality rates and trends across population groups or areas may provide important insights into the impact of cancer control interventions, such as smoking cessation, cancer screening, physical activity campaigns, and cancer treatment [3–5, 9].

Reliable individual-level socioeconomic data are lacking on US death certificates, which provide the basis for computing cancer mortality rates for various demographic groups and geographic areas [3–5, 9, 19]. Consequently, population-based studies of cancer mortality disparities in the US have generally utilized ecologic socioeconomic data linked to both individual- and aggregate-level cancer data [3–5, 7, 9, 14].

Although a number of studies have examined area-based socioeconomic disparities in cancer mortality [3–5, 9, 14], variations in US cancer mortality rates according to levels of rurality or urbanization are less well studied. Moreover, few studies have explored the relative impacts of deprivation and urbanization in explaining area variations in cancer mortality [5].

In Part I of this paper, we use a comprehensive area-based socioeconomic deprivation index and a rural-urban continuum variable to examine (1) the most current socioeconomic and rural-urban disparities in US all-cancer and lung cancer mortality, (2) differential patterns by sex and race, and (3) the relative importance of deprivation and rural-urban residence in explaining geographic disparities in cancer mortality rates. Since lung cancer largely drives the overall patterns in cancer mortality, we analyze inequalities in mortality from all cancers combined and lung cancer [19–22]. In Part II, we analyze disparities in mortality from four other major cancers: colon/rectum, prostate, breast, and uterine cervix.

1.2. Methods. To analyze socioeconomic and rural-urban disparities in cancer mortality, we used three national data sources: the national mortality database, the decennial census, and the 2009–2010 Area Resource File [15, 19, 23, 24]. Since the vital-statistics-based national mortality database lacks reliable socioeconomic data, socioeconomic patterns in mortality were derived by linking county-level socioeconomic data from the 2000 decennial census with the national mortality statistics [3–5, 9].

We used a factor-based deprivation index that consisted of 11 census-based social indicators, which may be viewed as broadly representing educational opportunities, labor force skills, economic, and housing conditions in a given county [3, 4, 25–27]. Selected indicators of education, occupation, wealth, income distribution, unemployment rate, poverty

rate, and housing quality were used to construct the index [3, 4, 25–27]. The factor loadings (correlations of indicators with the index) ranged from 0.92 for median family income to 0.49 for household plumbing [25]. The deprivation index had a mean value of 100 and a standard deviation of 20. Higher index scores denote higher levels of SES and lower levels of deprivation. The index score varied from a high of 179.8 for Marin County, California, to a low of 15.1 for Starr County, Texas [25]. Substantive and methodological details of the US deprivation index are provided elsewhere [3, 4, 25–27].

To analyze socioeconomic disparities in mortality rates, we used the weighted population distribution of the deprivation index that classified all 3,141 US counties into 10 groups of approximately equal population size [25]. The groups thus created ranged from being the most deprived (first decile) to the least disadvantaged (tenth decile) population groups [25]. A majority of the deprived counties were concentrated in the Southeastern region, whereas many of the affluent counties were located in the Northeastern and Western regions of the United States (Figure 1). The 2000 deprivation index was used to compute mortality rates for the 2003–2007 time period. Each of the 3,141 counties in the mortality database was assigned one of the 10 deprivation categories [25]. To simplify analysis and data presentation, we combined the 4th through 7th deciles of the deprivation index since mortality rates did not vary greatly among these middle-deprivation categories.

To analyze rural-urban disparities in cancer mortality, we extracted from the Area Resource File a rural-urban continuum variable that was developed in 2003 by the US Department of Agriculture [24]. This variable classifies all US counties into 9 distinct groups in the order of decreasing urbanization levels or increasing levels of rurality, based on the population size of the counties and their proximity to metropolitan areas [24, 28]. The 9 categories are defined as follows: (1) most urban = counties of metropolitan areas of ≥ 1 million population; (2) 2nd most urban = counties in metropolitan areas of 250,000–1,000,000 population; (3) 3rd most urban = counties in metropolitan areas of $< 250,000$ population; (4) 4th most urban = urban nonmetropolitan counties with population $\geq 20,000$, adjacent to a metropolitan area; (5) 5th most urban = urban nonmetropolitan counties with population $\geq 20,000$, not adjacent to a metropolitan area; (6) 6th most urban = urban nonmetropolitan counties with population of 2,500–19,999, adjacent to a metropolitan area; (7) 7th most urban = urban nonmetropolitan counties with population of 2,500–19,999, not adjacent to a metropolitan area; (8) 2nd most rural = rural counties with population $< 2,500$, adjacent to a metropolitan area; (9) most rural = rural counties with population $< 2,500$, not adjacent to a metropolitan area. For the purpose of computing mortality rates, we combined these 9 categories into 5 groups: large metropolitan county group (code 1); medium metropolitan county group (code 2); small metropolitan county group (code 3); urban nonmetropolitan county group (codes 4–7); rural nonmetropolitan county group (codes 8–9). The number of counties in these 5 county groups were 414, 325, 351, 1381, and 670, respectively. The 5 county groups accounted

TABLE 1: Age-adjusted all-cancer and lung cancer mortality rates per 100,000 population and relative risk (RR) of mortality according to socioeconomic deprivation deciles and five rural-urban categories, United States, 2003–2007.

	Age-adjusted mortality			Age-adjusted mortality			Age-adjusted mortality		
	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR
All-cancer mortality	Total population			All males			All females		
Socioeconomic deprivation index									
Socioeconomic decile 1	200.24	0.36	1.19*	255.76	0.63	1.29*	161.17	0.44	1.08*
Socioeconomic decile 2	192.21	0.34	1.14*	241.23	0.59	1.21*	158.17	0.42	1.06*
Socioeconomic decile 3	191.46	0.34	1.14*	237.48	0.59	1.19*	159.35	0.42	1.07*
Socioeconomic deciles 4–7	184.10	0.18	1.10*	224.71	0.30	1.13*	156.57	0.22	1.05*
Socioeconomic decile 8	176.71	0.34	1.05*	212.58	0.58	1.07*	152.46	0.42	1.02*
Socioeconomic decile 9	174.65	0.37	1.04*	210.81	0.63	1.06*	151.08	0.45	1.02*
Socioeconomic decile 10	168.03	0.34	1.00	198.82	0.58	1.00	148.78	0.42	1.00
Rural-urban continuum category									
Large metro counties ¹	179.47	0.15	1.00	217.61	0.27	1.00	154.38	0.19	1.00
Medium metro counties ²	182.46	0.25	1.02*	224.41	0.42	1.03*	153.66	0.30	1.00
Small metro counties ³	188.99	0.35	1.05*	234.17	0.61	1.08*	157.81	0.43	1.02*
Urban nonmetro counties ⁴	194.74	0.27	1.09*	242.97	0.47	1.12*	160.26	0.34	1.04*
Rural counties ⁵	193.27	0.75	1.08*	240.29	1.25	1.10*	157.56	0.93	1.02*
All-cancer mortality	All whites			All blacks			Black male		
Socioeconomic deprivation index									
Socioeconomic decile 1	196.47	0.40	1.15*	232.91	1.03	1.20*	320.23	1.96	1.33*
Socioeconomic decile 2	189.24	0.37	1.10*	223.17	1.09	1.15*	301.95	2.10	1.25*
Socioeconomic decile 3	189.35	0.36	1.11*	230.83	1.38	1.19*	305.36	2.57	1.26*
Socioeconomic deciles 4–7	181.80	0.19	1.06*	230.60	0.65	1.19*	302.20	1.22	1.25*
Socioeconomic decile 8	176.19	0.36	1.03*	209.84	1.40	1.08*	273.18	2.68	1.13*
Socioeconomic decile 9	176.91	0.40	1.03*	214.48	1.64	1.11*	275.01	3.13	1.14*
Socioeconomic decile 10	171.28	0.36	1.00	193.69	1.62	1.00	241.61	3.04	1.00
Rural-urban continuum category									
Large metro counties ¹	177.85	0.17	1.00	221.03	0.51	1.00	311.59	1.43	1.00
Medium metro counties ²	181.18	0.26	1.02*	226.70	1.03	1.03*	305.23	1.80	0.98*
Small metro counties ³	186.95	0.37	1.05*	233.77	1.54	1.06*	305.92	1.57	0.98*
Urban nonmetro counties ⁴	192.94	0.28	1.08*	236.45	1.23	1.07*	277.64	2.01	0.89*
Rural counties ⁵	190.69	0.78	1.07*	228.65	3.44	1.03*	259.05	2.18	0.83*
Lung cancer mortality	Total population			All males			All females		
Socioeconomic deprivation index									
Socioeconomic decile 1	61.57	0.20	1.42*	87.46	0.37	1.66*	42.20	0.22	1.14*
Socioeconomic decile 2	57.24	0.19	1.32*	79.01	0.34	1.50*	41.12	0.21	1.11*
Socioeconomic decile 3	57.20	0.19	1.32*	76.33	0.33	1.45*	43.00	0.22	1.16*
Socioeconomic deciles 4–7	52.49	0.43	1.21*	68.16	0.17	1.30*	41.05	0.11	1.11*
Socioeconomic decile 8	48.26	0.18	1.11*	60.21	0.31	1.15*	39.50	0.22	1.07*
Socioeconomic decile 9	47.46	0.19	1.09*	58.85	0.33	1.12*	39.41	0.23	1.07*
Socioeconomic decile 10	43.39	0.17	1.00	52.56	0.29	1.00	37.00	0.21	1.00
Rural-urban continuum category									
Large metro counties	49.27	0.08	1.00	63.05	0.14	1.00	39.42	0.10	1.00
Medium metro counties	52.70	0.13	1.07*	69.05	0.23	1.10*	40.66	0.16	1.03*
Small metro counties	56.54	0.19	1.15*	75.20	0.34	1.19*	42.71	0.23	1.08*
Urban nonmetro counties	59.02	0.15	1.20*	79.93	0.26	1.27*	43.05	0.17	1.09*
Rural counties	58.37	0.41	1.18*	80.18	0.71	1.27*	40.73	0.47	1.03*

TABLE 1: Continued.

	Age-adjusted mortality			Age-adjusted mortality			Age-adjusted mortality		
	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR
Lung cancer mortality	All whites			White male			White female		
Socioeconomic deprivation index									
Socioeconomic decile 1	62.34	0.22	1.39*	86.74	0.40	1.62*	43.80	0.25	1.13*
Socioeconomic decile 2	57.90	0.20	1.29*	78.76	0.36	1.48*	42.16	0.23	1.09*
Socioeconomic decile 3	57.18	0.20	1.28*	75.51	0.34	1.41*	43.52	0.23	1.12*
Socioeconomic deciles 4–7	52.53	0.10	1.17*	67.17	0.17	1.26*	41.76	0.12	1.08*
Socioeconomic decile 8	48.64	0.19	1.09*	59.80	0.32	1.12*	40.41	0.23	1.04*
Socioeconomic decile 9	48.78	0.21	1.09*	59.54	0.36	1.12*	41.28	0.26	1.06*
Socioeconomic decile 10	44.73	0.19	1.00	53.38	0.32	1.00	38.78	0.23	1.00
Rural-urban continuum category									
Large metro counties	49.61	0.09	1.00	62.20	0.15	1.00	40.57	0.11	1.00
Medium metro counties	52.93	0.14	1.07*	68.40	0.24	1.10*	41.50	0.17	1.02*
Small metro counties	56.44	0.20	1.14*	74.16	0.35	1.19*	43.29	0.24	1.07*
Urban nonmetro counties	59.25	0.16	1.19*	79.27	0.27	1.27*	43.91	0.18	1.08*
Rural counties	58.14	0.43	1.17*	79.09	0.73	1.27*	41.08	0.50	1.01
Lung cancer mortality	All blacks			Black male			Black female		
Socioeconomic deprivation index									
Socioeconomic decile 1	61.99	0.53	1.35*	100.03	1.08	1.60*	36.83	0.53	1.07*
Socioeconomic decile 2	56.13	0.54	1.23*	86.74	1.11	1.38*	36.89	0.57	1.07*
Socioeconomic decile 3	63.12	0.72	1.38*	94.55	1.41	1.51*	41.73	0.76	1.21*
Socioeconomic deciles 4–7	61.31	0.33	1.34*	89.91	0.65	1.43*	42.52	0.36	1.23*
Socioeconomic decile 8	53.11	0.71	1.16*	76.77	1.39	1.23*	37.93	0.77	1.10*
Socioeconomic decile 9	53.97	0.82	1.18*	75.76	1.58	1.21*	39.40	0.90	1.14*
Socioeconomic decile 10	45.81	0.79	1.00	62.66	1.50	1.00	34.51	0.88	1.00
Rural-urban continuum category									
Large metro counties	57.04	0.26	1.00	82.44	0.50	1.00	40.71	0.28	1.00
Medium metro counties	60.15	0.53	1.05*	92.15	1.06	1.12*	38.77	0.55	0.95*
Small metro counties	63.87	0.81	1.12*	100.09	1.62	1.21*	39.07	0.82	0.96
Urban nonmetro counties	62.85	0.64	1.10*	101.31	1.28	1.23*	36.09	0.63	0.89*
Rural counties	60.59	1.78	1.06*	100.26	3.55	1.22*	32.14	1.72	0.79*

Mortality rates are age adjusted to the 2000 US standard population. * $P < 0.05$.

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

For computing relative risks of cancer mortality, the tenth socioeconomic decile and large metro counties were treated as reference categories.

¹Counties in metropolitan areas with 1 million population or more. ²Counties in metropolitan areas of 250,000–1,000,000 population.

³Counties in metropolitan areas with population <250,000. ⁴Urban nonmetro counties. ⁵Rural counties with no places with a population of 2,500+.

for 53.6%, 20.0%, 9.9%, 14.9%, and 1.7% of the total US population in 2007, respectively [25]. Most of the nonmetropolitan and rural counties are in the Midwest and Great Plains regions of the US, whereas many of the large metropolitan counties are located in the Northeast (Figure 1).

Age-sex-race-county-specific population estimates from 2003 to 2007 developed by the US Census Bureau served as denominators for computing average annual mortality rates [15, 19, 20]. During 2003–2007, there were 1,448,140 male cancer deaths and 1,344,680 female cancer deaths in the US. Of these, lung cancer accounted for 447,192 deaths among men and 345,303 among women. Mortality rates for each county, area-socioeconomic group, or rural-urban category were age-adjusted by the direct method using the age

composition of the 2000 US population as the standard and age-specific mortality rates for 19 age groups: <1, 1–4, 5–9, 10–14, . . . , 80–84, 85+ years [5, 19, 20].

Weighted least squares regression models were fitted to county-level age-adjusted cancer mortality rates to estimate socioeconomic and rural-urban gradients in cancer mortality for the 2003–2007 period and to assess their relative impacts. The effects of both categorical and continuous measures of the deprivation index and rural-urban continuum were estimated in the regression models. Deaths from all cancers and lung cancer in each county were used as weights in the weighted regression models because the number of deaths is proportional to the inverse of the variance of mortality rates [19, 20]. For the black population, however,

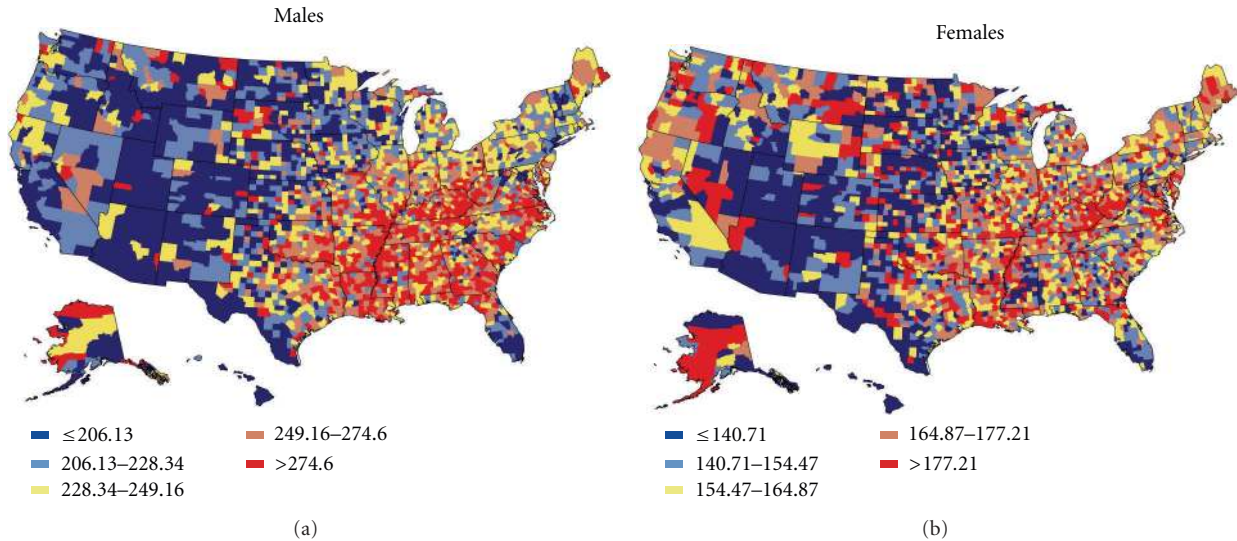


FIGURE 2: All-cancer mortality rates per 100,000 population (age adjusted to the 2000 population), US males and females, 2003–2007 (3,141 counties).

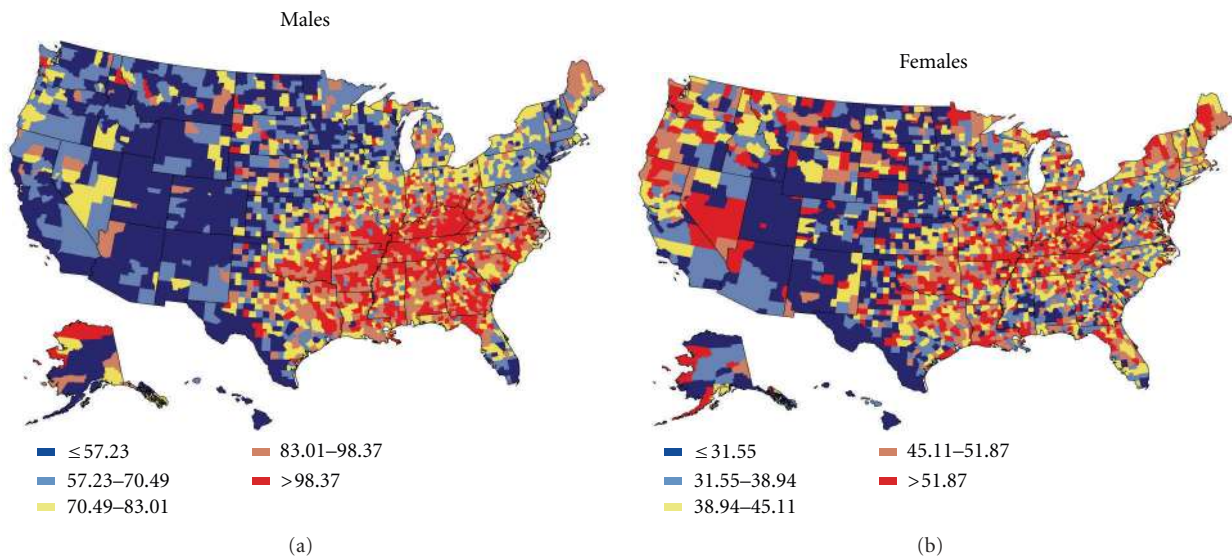


FIGURE 3: Lung cancer mortality rates per 100,000 population (age adjusted to the 2000 population), US males and females, 2003–2007 (3,141 counties).

1.3.2. Disparities in Lung Cancer Mortality. Socioeconomic gradients and absolute inequalities in lung cancer mortality were large and consistent for the total population and for men in particular. Compared to their counterparts in the least-deprived group, men and women in the most-deprived group had 66% and 14% higher lung cancer mortality rates, respectively (Table 1). While higher deprivation levels were generally associated with higher lung cancer mortality rates for white men, white women, and black men, the relationship was less consistent for black women.

People in rural areas had 18–20% higher lung cancer mortality than those in urban areas, with the degree of rurality being particularly associated with increased lung cancer mortality risks among men (Table 1). No significant

association between urbanization and lung cancer mortality was found for white women. However, higher levels of rurality were associated with substantially increased lung cancer mortality rates for white men. Rural-urban patterns in lung cancer mortality also differed between black men and women. Black men in rural areas had 22% higher mortality than black men in the most-urbanized counties, whereas black women in rural areas had 21% lower mortality than black women in the most-urbanized counties.

Geographical distributions of SES and lung cancer mortality were closely related, with the weighted correlations being -0.58 for men and -0.26 for women (see Figures 1 and 3 and β 's in bivariate models of Table 3). Consistent with high deprivation levels in the Southeast, men and women in this

region had the highest lung cancer mortality rates (Figure 3). In the multivariate models, both deprivation and urbanization levels contributed significantly to disparities in male and female lung cancer mortality rates, with deprivation having a 6.4 times larger impact for men and 2.6 times larger impact for women than rural-urban residence (Tables 2 and 3). The deprivation index and rural-urban continuum jointly accounted for 34.1% of the variance in male lung mortality rates (Table 3). Each 10-point increase in the deprivation level was associated with a 5.57-point increase in the male lung cancer mortality rate, whereas a one-unit increase in rural-urban continuum (i.e., toward higher levels of rurality) was associated with a 0.83-point increase in the male lung cancer mortality rate (Table 3).

After adjusting for rural-urban residence, men and women in the most-deprived group had 69% and 17% higher lung cancer mortality risks than their most affluent counterparts, respectively (Table 2). While both deprivation and rural-urban residence had significant impacts on lung cancer mortality among whites, only deprivation levels were significantly related to increased lung cancer mortality among blacks (Table 3).

Socioeconomic gradients and rate differences in lung cancer mortality were more marked in nonmetropolitan than in metropolitan areas (Table 4). For example, in nonmetropolitan areas, men in the two most-deprived groups had 3.2 and 2.7 times higher lung cancer mortality rates than their counterparts in the least-deprived group, respectively. On the other hand, in metropolitan areas, men in the two most-deprived groups had 1.4 and 1.5 times higher lung cancer mortality rates than men in the least-deprived group.

1.4. Discussion. In Part I of this study, we used a comprehensive area-based deprivation index and a rural-urban continuum measure to examine socioeconomic, rural-urban, and racial disparities in US all-cancer and lung cancer mortality. To our knowledge, this is first US study to systematically examine the independent and joint effects of deprivation and urbanization on cancer mortality. The deprivation index is a summary representation of general living standards and socioeconomic conditions in US counties and has been shown to capture both absolute and distributive aspects of community socioeconomic disadvantage [3, 4, 25–27]. It is a powerful surveillance tool that has been used previously to analyze population-based health disparities over time in site-specific cancer mortality, all-cause and cardiovascular mortality, infant and child mortality, and life expectancy in the United States [3, 4, 25–27, 31, 32].

Both socioeconomic deprivation and rural-urban continuum contributed significantly to disparities in all-cancer and lung cancer mortality. Excess mortality risks associated with deprivation and rurality were more marked for lung cancer than for all-cancer mortality, with the magnitude and patterns of inequalities varying by race and sex. Deprivation levels mostly accounted for the relationship between rural-urban continuum and all-cancer mortality. However, lung cancer mortality was generally higher in rural than in urban areas, even after adjusting for deprivation levels. In almost every instance, socioeconomic deprivation had a stronger

impact and explained more of the variance in geographic disparities in all-cancer and lung cancer mortality than rural-urban continuum.

When we compare the current socioeconomic disparities in US cancer mortality with those that existed during the 1990s, the magnitude of disparities appears to have widened [3–5]. Socioeconomic gradients in male cancer mortality have continued to persist, while those in female cancer mortality widened during 2003–2007. In 1998, no significant socioeconomic differences in all-cancer mortality among women existed [3], whereas, in 2003–2007, women in the most-deprived group had 8% higher mortality than women in the least-deprived group. Socioeconomic gradients in lung cancer mortality among both men and women were steeper in 2003–2007 than in 1998 [4]. In our study, male lung cancer mortality rates in 2003–2007 were 66% higher in the most-deprived group than in the least-deprived group; in 1998, mortality was 44% higher in the most-deprived group [4]. While female lung cancer mortality rates did not differ by SES in 1998 [4], they were 14% higher in 2003–2007 among women in the most-deprived group. The continued widening of socioeconomic disparities in lung cancer mortality since the 1980s appears to be consistent with increasing socioeconomic disparities in smoking, as smoking rates have fallen more rapidly over time for men and women in higher SES groups [4, 5, 15].

Both relative and absolute socioeconomic differences in all-cancer and lung cancer mortality were larger in nonmetropolitan than in metropolitan areas. A possible reason for the steeper gradients in nonmetropolitan areas is that socioeconomic disparities in cancer-risk factors (such as smoking, diet, and physical inactivity), survival, and stage at diagnosis, and healthcare access and utilization may be more marked in rural than urban areas.

Socioeconomic and rural-urban disparities in cigarette smoking, undoubtedly, contribute to inequalities in all-cancer and lung cancer mortality shown here. Higher smoking rates are not only more prevalent among men and women in lower SES groups and in more deprived areas, but they are also more prevalent among residents of small towns and rural areas [15, 30]. Residents in rural and nonmetropolitan areas are one-third more likely to smoke than their urban counterparts [30, 33]. Individuals in lower SES groups also have substantially longer durations of smoking and lower cessation rates than those in higher SES groups [34]. Besides smoking rates, socioeconomic and rural-urban disparities in all-cancer and lung cancer mortality may be related to area differences in tobacco regulation and advertising, availability of cigarettes, public awareness of the harmful health effects of smoking, cancer screening, and healthcare factors [5, 15, 35–39]. Healthcare disparities may also play a prominent role in producing social inequalities in cancer mortality. Residents in more deprived neighborhoods have been shown to have substantially higher rates of late-stage cancer diagnoses and significantly lower rates of cancer survival than their counterparts from more affluent neighborhoods [5, 9, 40–50]. Although the majority of lung cancer cases are diagnosed at distant stage, residents of more deprived areas

TABLE 2: Multivariate weighted least squares regression models showing adjusted differentials in all-cancer and lung cancer mortality rates per 100,000 population according to socioeconomic deprivation deciles and five rural-urban categories, United States, 2003–2007.

	Predicted mortality rate			Predicted mortality rate			Predicted mortality rate		
	Mean	SE	<i>P</i> value	Mean	SE	<i>P</i> value	Mean	SE	<i>P</i> value
All cancer mortality	Total Population			Male			Female		
Socioeconomic deprivation index									
Socioeconomic decile 1	204.64	1.20	<0.001	264.32	1.73	<0.001	165.29	1.04	<0.001
Socioeconomic decile 2	195.67	1.19	<0.001	246.44	1.73	<0.001	161.77	1.02	<0.001
Socioeconomic decile 3	193.35	1.20	<0.001	240.38	1.74	<0.001	161.52	1.02	<0.001
Socioeconomic deciles 4–7	187.18	0.84	<0.001	228.64	1.22	<0.001	159.25	0.71	<0.001
Socioeconomic decile 8	180.87	1.37	<0.001	218.39	2.03	<0.001	155.80	1.15	<0.001
Socioeconomic decile 9	177.50	1.48	<0.001	213.91	2.19	0.064	153.47	1.23	0.057
Socioeconomic decile 10	170.65	1.49	Reference	201.72	2.23	Reference	150.65	1.23	Reference
Rural-urban continuum category									
Large metro counties	186.03	0.62	Reference	229.16	0.91	Reference	158.15	0.51	Reference
Medium metro counties	185.40	0.90	0.544	229.99	1.32	0.583	155.96	0.75	0.011
Small metro counties	187.69	1.21	0.218	232.20	1.77	0.126	158.16	1.02	0.997
Urban non-metro counties	189.55	0.99	0.004	233.09	1.44	0.029	159.81	0.84	0.111
Rural counties	186.94	2.50	0.728	228.28	3.56	0.814	159.17	2.17	0.656
All cancer mortality	All whites			All blacks			Black male		
Socioeconomic deprivation index									
Socioeconomic decile 1	200.40	1.16	<0.001	229.69	2.60	<0.001	316.78	4.61	<0.001
Socioeconomic decile 2	192.32	1.12	<0.001	221.83	2.89	<0.001	299.29	5.12	<0.001
Socioeconomic decile 3	191.52	1.10	<0.001	228.84	3.28	<0.001	302.99	5.79	<0.001
Socioeconomic deciles 4–7	185.84	0.77	<0.001	232.03	2.39	<0.001	304.38	4.21	<0.001
Socioeconomic decile 8	182.37	1.27	<0.001	213.47	3.42	<0.001	280.86	6.05	<0.001
Socioeconomic decile 9	181.06	1.39	0.003	213.68	3.61	<0.001	276.02	6.39	0.057
Socioeconomic decile 10	175.97	1.38	Reference	193.03	3.89	Reference	243.82	6.89	Reference
Rural-urban continuum category									
Large metro counties	183.91	0.60	Reference	215.91	1.17	Reference	282.00	2.11	Reference
Medium metro counties	184.67	0.83	0.433	216.07	2.14	0.946	290.10	3.80	0.046
Small metro counties	187.69	1.11	0.003	225.30	3.14	0.005	297.93	5.54	0.007
Urban non-metro counties	190.82	0.90	<0.001	225.76	3.03	0.003	299.43	5.27	0.003
Rural counties	188.26	2.27	0.070	211.65	8.36	0.615	276.36	14.53	0.702
Lung cancer mortality	Total population			Male			Female		
Socioeconomic deprivation index									
Socioeconomic decile 1	66.38	0.61	<0.001	96.05	0.89	<0.001	46.28	0.52	<0.001
Socioeconomic decile 2	60.89	0.61	<0.001	84.28	0.90	<0.001	45.02	0.52	<0.001
Socioeconomic decile 3	59.26	0.61	<0.001	79.53	0.92	<0.001	45.32	0.51	<0.001
Socioeconomic deciles 4–7	55.52	0.43	<0.001	72.62	0.65	<0.001	43.80	0.36	<0.001
Socioeconomic decile 8	51.81	0.73	<0.001	65.43	1.13	<0.001	42.62	0.58	<0.001
Socioeconomic decile 9	50.48	0.79	0.064	63.24	1.23	0.064	42.07	0.63	0.064
Socioeconomic decile 10	46.28	0.81	Reference	56.70	1.27	Reference	39.45	0.63	Reference
Rural-urban continuum category									
Large metro counties	53.72	0.33	Reference	70.89	0.50	Reference	41.92	0.26	Reference
Medium metro counties	54.92	0.47	0.026	73.31	0.72	0.004	42.20	0.38	0.519
Small metro counties	56.47	0.62	<0.001	75.29	0.94	<0.001	43.56	0.51	0.004
Urban non-metro counties	57.04	0.51	<0.001	75.36	0.77	<0.001	44.49	0.42	<0.001
Rural counties	56.86	1.27	0.019	75.05	1.86	0.034	45.36	1.10	0.003

TABLE 2: Continued.

	Predicted mortality rate			Predicted mortality rate			Predicted mortality rate		
	Mean	SE	P value	Mean	SE	P value	Mean	SE	P value
Lung cancer mortality	All whites			White male			White female		
Socioeconomic deprivation index									
Socioeconomic decile 1	67.62	0.62	<0.001	95.74	0.91	<0.001	48.51	0.53	<0.001
Socioeconomic decile 2	60.39	0.61	<0.001	82.21	0.90	<0.001	45.47	0.51	<0.001
Socioeconomic decile 3	58.89	0.60	<0.001	78.02	0.90	<0.001	45.68	0.50	<0.001
Socioeconomic deciles 4–7	55.34	0.42	<0.001	71.49	0.63	<0.001	44.27	0.34	<0.001
Socioeconomic decile 8	52.29	0.70	<0.001	65.16	1.08	<0.001	43.56	0.55	<0.001
Socioeconomic decile 9	51.53	0.81	<0.001	63.95	1.27	<0.001	43.39	0.64	0.001
Socioeconomic decile 10	47.41	0.83	Reference	57.79	1.30	Reference	40.76	0.65	Reference
Rural-urban continuum category									
Large metro counties	54.32	0.35	Reference	70.44	0.53	Reference	43.19	0.28	Reference
Medium metro counties	55.45	0.48	0.044	72.71	0.73	0.008	43.46	0.39	0.557
Small metro counties	57.33	0.63	<0.001	75.54	0.95	<0.001	44.86	0.52	0.005
Urban nonmetro counties	57.36	0.50	<0.001	75.00	0.75	<0.001	45.37	0.41	<0.001
Rural counties	56.59	1.10	0.054	73.71	1.62	0.062	45.72	0.94	0.012
Lung cancer mortality	All blacks			Black male			Black female		
Socioeconomic deprivation index									
Socioeconomic decile 1	61.12	1.37	<0.001	99.10	2.61	<0.001	35.93	1.03	<0.001
Socioeconomic decile 2	55.30	1.53	<0.001	85.69	2.90	<0.001	34.46	1.15	0.006
Socioeconomic decile 3	63.01	1.73	<0.001	95.35	3.28	<0.001	39.83	1.30	<0.001
Socioeconomic deciles 4–7	61.71	1.26	<0.001	92.93	2.39	<0.001	39.23	0.95	<0.001
Socioeconomic decile 8	55.56	1.80	<0.001	83.91	3.43	<0.001	35.74	1.36	<0.001
Socioeconomic decile 9	54.27	1.90	<0.001	78.62	3.63	<0.001	35.81	1.43	<0.001
Socioeconomic decile 10	45.17	2.05	Reference	64.91	3.91	Reference	30.07	1.53	Reference
Rural-urban continuum category									
Large metro counties	53.86	0.62	Reference	78.30	1.19	Reference	38.30	0.46	Reference
Medium metro counties	56.31	1.13	0.041	86.82	2.16	<0.001	36.40	0.84	0.033
Small metro counties	58.84	1.66	0.005	88.54	3.14	0.002	37.57	1.25	0.582
Urban nonmetro counties	59.25	1.60	0.002	90.80	2.99	<0.001	35.99	1.22	0.081
Rural counties	54.70	4.41	0.851	84.47	8.24	0.461	31.08	3.36	0.034

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

are significantly more likely to be diagnosed with late-stage lung cancer [5].

Lack of health insurance, limited access to care, and lower rates of cancer screening among residents of rural and more disadvantaged areas may account for their higher rates of late-stage cancer diagnoses [5, 15, 30, 44–46]. However, lower cancer survival rates among poorer residents are not merely due to their higher rates of late-stage cancer diagnoses, but differences in preferred treatment for lung and other cancers may also contribute to their lower survival and higher cancer mortality rates [5, 46].

1.4.1. Interpretation of Race-Specific Patterns and Inequalities.

Deprivation and urbanization levels do not quite account for marked racial disparities in cancer mortality. It is important to note that the total cancer mortality rate for blacks in the most-affluent group was similar to the rate for whites in the most-deprived group. Within each deprivation group, blacks

had higher all-cancer mortality rates than whites. What factors might explain such disparities? One possible explanation is that, within each area-deprivation group, blacks remain worse off than whites as they have significantly lower education and income levels and higher rates of poverty, unemployment, and lack of health insurance. According to the 2000 census data, within the most-deprived SES decile, blacks had twice the poverty and unemployment rates of whites (poverty rate 32.2% versus 16.5% and unemployment rate 14.5% versus 6.6%). Indeed, the unemployment rate of blacks in the most-affluent area group (7.3%) exceeded that of whites in the most-deprived group (6.6%). Moreover, within each education or income level, blacks have higher prevalence of smoking, obesity, and physical inactivity. In 2009, 39.1% of black males without a high school diploma smoked, compared with 32.2% of white males with a similar education level; the corresponding race-specific smoking rates among females were 31.0% and 24.4% [15]. During

TABLE 3: Weighted least squares regression models¹ showing the relative impacts of the continuous socioeconomic deprivation index² and rural-urban continuum³ on county-level age-adjusted mortality rates for all cancers combined and lung cancer, United States, 2003–2007 ($N = 3141$).

Covariate	Bivariate models					Multivariate models				
	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. R^2	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. R^2
All cancer mortality—total population										
Socioeconomic deprivation index	−0.504	−0.428	−26.54	<0.001	18.31	−0.483	−0.410	−21.03	<0.001	18.36
Rural-urban continuum	3.098	0.263	15.25	<0.001	6.87	0.381	0.032	1.66	0.098	
All cancer mortality—male										
Socioeconomic deprivation index	−0.893	−0.495	−31.88	<0.001	24.44	−0.864	−0.479	−25.40	<0.001	24.47
Rural-urban continuum	5.340	0.300	17.60	<0.001	8.96	0.502	0.028	1.50	0.135	
All cancer mortality—female										
Socioeconomic deprivation index	−0.228	−0.247	−14.28	<0.001	6.08	−0.224	−0.243	−11.66	<0.001	6.12
Rural-urban continuum	1.340	0.143	8.07	<0.001	2.01	0.075	0.008	0.38	0.703	
All cancer mortality—white										
Socioeconomic deprivation index	−0.405	−0.371	−22.39	<0.001	13.77	−0.338	−0.310	−15.39	<0.001	14.49
Rural-urban continuum	3.037	0.284	16.61	<0.001	8.06	1.134	0.106	5.27	<0.001	
All cancer mortality—white male										
Socioeconomic deprivation index	−0.746	−0.453	−28.47	<0.001	20.53	−0.645	−0.392	−20.19	<0.001	21.25
Rural-urban continuum	5.280	0.333	19.73	<0.001	11.03	1.676	0.106	5.43	<0.001	
All cancer mortality—white female										
Socioeconomic deprivation index	−0.147	−0.167	−9.47	<0.001	2.76	−0.110	−0.124	−5.82	<0.001	3.11
Rural-urban continuum	1.277	0.146	8.23	<0.001	2.09	0.657	0.075	3.50	<0.001	
All cancer mortality—black										
Socioeconomic deprivation index	−0.504	−0.205	11.69	<0.001	4.19	−0.533	−0.217	−10.3	<0.001	4.19
Rural-urban continuum	3.001	0.099	5.52	<0.001	0.94	−0.627	−0.021	−0.98	0.327	
All cancer mortality—black male										
Socioeconomic deprivation index	−1.036	−0.238	−13.58	<0.001	5.61	−1.034	−0.237	−11.28	<0.001	5.58
Rural-urban continuum	7.025	0.132	7.41	<0.001	1.72	0.036	0.001	0.03	0.974	
All cancer mortality—black female										
Socioeconomic deprivation index	−0.178	−0.077	−4.31	<0.001	0.57	−0.262	−0.114	−5.31	<0.001	0.85
Rural-urban continuum	−0.123	−0.004	−0.24	0.814	0.00	−1.925	−0.067	−3.10	0.002	
Lung cancer mortality—total population										
Socioeconomic deprivation index	−0.319	−0.495	−31.87	<0.001	24.47	−0.287	−0.445	−23.33	<0.001	24.92
Rural-urban continuum	2.173	0.345	20.57	<0.001	11.88	0.534	0.085	4.44	<0.001	
Lung cancer mortality—male										
Socioeconomic deprivation index	−0.609	−0.580	−39.77	<0.001	33.63	−0.557	−0.531	−29.48	<0.001	34.05
Rural-urban continuum	3.978	0.397	24.12	<0.001	15.70	0.830	0.083	4.59	<0.001	
Lung cancer mortality—female										
Socioeconomic deprivation index	−0.125	−0.264	−15.26	<0.001	6.95	−0.102	−0.216	−10.24	<0.001	7.40
Rural-urban continuum	0.989	0.208	11.86	<0.001	4.30	0.400	0.084	3.99	<0.001	
Lung cancer mortality—white										
Socioeconomic deprivation index	−0.312	−0.478	−30.41	<0.001	22.84	−0.286	−0.438	−22.64	<0.001	23.12
Rural-urban continuum	1.942	0.325	19.18	<0.001	10.51	0.408	0.068	3.53	<0.001	
Lung cancer mortality—white male										
Socioeconomic deprivation index	−0.586	−0.558	−37.52	<0.001	31.15	−0.540	−0.515	−28.01	<0.001	31.48
Rural-urban continuum	3.572	0.377	22.73	<0.001	14.22	0.699	0.074	4.02	<0.001	
Lung cancer mortality—white female										
Socioeconomic deprivation index	−0.126	−0.261	−15.00	<0.001	6.77	−0.107	−0.221	−10.41	<0.001	7.06
Rural-urban continuum	0.887	0.196	11.12	<0.001	3.82	0.310	0.069	3.23	<0.001	

TABLE 3: Continued.

Covariate	Bivariate models					Multivariate models				
	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. <i>R</i> ²	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. <i>R</i> ²
Lung cancer mortality—black										
Socioeconomic deprivation index	-0.195	-0.152	-8.56	<0.001	2.28	-0.178	-0.139	-6.52	<0.001	2.29
Rural-urban continuum	1.601	0.101	5.63	<0.001	0.98	0.386	0.024	1.14	0.254	
Lung cancer mortality—black male										
Socioeconomic deprivation index	-0.474	-0.192	-10.88	<0.001	3.67	-0.396	-0.161	-7.59	<0.001	3.85
Rural-urban continuum	4.374	0.146	8.18	<0.001	2.09	1.695	0.056	2.66	0.008	
Lung cancer mortality—black female										
Socioeconomic deprivation index	-0.011	-0.012	-0.65	0.517	0.01	-0.061	-0.065	-3.03	0.003	0.62
Rural-urban continuum	-0.735	-0.062	-3.44	<0.001	0.35	-1.157	-0.098	-4.54	<0.001	

Notes: *b*: unstandardized regression coefficient; β : standardized regression coefficient; *R*²: percentage variance explained.

β is also equal to the correlation coefficient in bivariate regression models.

¹The least squares regression models are weighted, with weights being cancer-specific deaths in each county.

²The 2000 census socioeconomic deprivation index is a continuous variable with a mean of 100 and a standard deviation of 20.

Higher index scores denote higher levels of socioeconomic position and lower levels of deprivation.

³The 2003 rural-urban continuum is used as a continuous variable, with code 1 being the most urbanized county and code 9 being the most rural county.

TABLE 4: Socioeconomic disparities in all-cancer and lung cancer mortality rates per 100,000 population and relative risks (RR) and gradients in mortality within metropolitan and nonmetropolitan areas of the United States, 2003–2007.

	Metropolitan areas						Nonmetropolitan areas					
	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR
All cancer mortality												
	Male			Female			Male			Female		
Socioeconomic deprivation index												
Socioeconomic decile 1	237.14	1.03	1.19*	154.66	0.71	1.04*	265.99	0.80	1.87*	165.06	0.56	1.25*
Socioeconomic decile 2	240.48	0.82	1.21*	156.05	0.56	1.05*	241.85	0.86	1.70*	160.61	0.63	1.22*
Socioeconomic decile 3	240.42	0.74	1.21*	160.06	0.52	1.08*	231.66	0.98	1.63*	157.71	0.73	1.20*
Socioeconomic deciles 4–7	224.94	0.32	1.13*	156.73	0.23	1.05*	222.62	0.94	1.57*	154.95	0.70	1.18*
Socioeconomic decile 8	212.89	0.59	1.07*	152.75	0.43	1.03*	205.36	2.90	1.45*	144.68	2.21	1.10*
Socioeconomic decile 9	211.09	0.64	1.06*	151.14	0.45	1.02*	196.62	4.37	1.38*	147.53	3.38	1.12*
Socioeconomic decile 10	199.09	0.58	1.00	148.88	0.42	1.00	141.97	8.21	1.00	131.56	7.01	1.00
Deprivation gradient ¹	-0.783*	0.051 ²		-0.188*	0.029		-1.208*	0.049		-0.337*	0.028	
Lung cancer mortality												
	Male			Female			Male			Female		
Socioeconomic deprivation index												
Socioeconomic decile 1	74.49	0.57	1.41*	38.21	0.35	1.03*	94.56	0.47	3.17*	44.54	0.29	1.41*
Socioeconomic decile 2	77.85	0.46	1.48*	39.00	0.28	1.05*	80.22	0.49	2.69*	43.74	0.33	1.38*
Socioeconomic decile 3	78.55	0.42	1.49*	43.51	0.27	1.17*	72.24	0.54	2.42*	42.07	0.38	1.33*
Socioeconomic deciles 4–7	68.31	0.17	1.30*	41.15	0.12	1.11*	66.94	0.51	2.24*	40.21	0.36	1.27*
Socioeconomic decile 8	60.26	0.31	1.14*	39.63	0.22	1.07*	58.91	1.53	1.97*	36.16	1.11	1.14*
Socioeconomic decile 9	59.02	0.33	1.12*	39.42	0.23	1.06*	50.30	2.18	1.69*	38.70	1.74	1.22*
Socioeconomic decile 10	52.66	0.30	1.00	37.03	0.21	1.00	29.83	3.59	1.00	31.61	3.51	1.00
Deprivation gradient	-0.513*	0.027		-0.091*	0.014		-0.817*	0.029		-0.183*	0.016	

Metropolitan areas consist of large metro counties of a million people or more and smaller metro counties of population <250,000.

Nonmetropolitan areas consist of small urban towns with a population <20,000 and rural towns with a population <2,500.

Mortality rates are age adjusted to the 2000 US standard population. **P* < 0.05.

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

For computing relative risks of cancer mortality, the tenth socioeconomic decile was treated as the reference category.

¹Measured by the slope or unstandardized regression coefficient associated with the continuous deprivation index. ²Standard error of slope.

2005–2008, 54.7% of poor black women aged ≥20 were obese, compared with 39.2% of poor white women; the obesity prevalence for high-income black and white women were 47.6% and 27.5%, respectively [51]. Moreover, in 2009, 66.2% of blacks below the poverty line were physically

inactive, compared with 58% of poor whites; the figures among affluent blacks and whites were 45.3% and 36.5%, respectively [15].

Secondly, although deprivation may partly account for racial disparities in cancer survival and stage at diagnosis,

black men and women in each deprivation group are significantly more likely to be diagnosed with a late-stage cancer and have lower rates of cancer survival, even after controlling for stage at diagnosis [5]. These disparities may reflect inequities in healthcare access, cancer screening, and treatment.

Thirdly, ethnic-minorities and socioeconomically disadvantaged populations have reduced access to medical care in the United States. In 2009, 18.8% of blacks aged <65 years lacked health insurance, compared with 13.2% of whites. Approximately 30% of poor adults aged <65 lacked health insurance, compared with only 5% of adults with incomes $\geq 400\%$ of the poverty threshold [15]. Minorities and low-SES adults were also substantially less likely to have a usual source of care or were more likely to forego or delay needed medical care than whites and high-SES adults, respectively [15].

Fourth, blacks and socioeconomically disadvantaged populations in the US are generally more likely to live in neighborhoods with unfavorable physical or built environmental characteristics, which put them at higher risks of obesity, sedentary behaviors, and poor diet [52, 53]. In 2007, 26% of black households were in unsafe neighborhoods, 27% in neighborhoods with litter/garbage on streets or sidewalks, 20% in neighborhoods with poor/dilapidated housing, and 14% in neighborhoods characterized by vandalism such as broken windows or graffiti, compared with 8%, 14%, 13%, and 8% of white households, respectively. Socially disadvantaged populations have markedly lower access to neighborhood sidewalks, parks/playgrounds, inadequate public transportation, and local grocery stores that carry healthy, affordable foods. Racial disparities in neighborhood conditions persist even after controlling for household SES [52].

1.4.2. Comparison with International Patterns. Although studies on cancer inequalities vary widely in their use of socioeconomic and urbanization measures and coverage of time periods, international comparisons can highlight important cross-national differences and similarities in socioeconomic conditions, rural-urban disparities, mortality risks, and prevalence of cancer risk factors such as smoking [54]. Socioeconomic and rural-urban disparities in US cancer mortality reported here are mostly consistent with patterns observed for the other industrialized countries. Consistent with the US pattern, all-cancer mortality rates in England during 2004–2006 and in Quebec, Canada, during 1994–1996 increased consistently by area deprivation levels [55, 56]. In several European populations such as Switzerland, France, Belgium, Denmark, Norway, Sweden, and Finland, cancer mortality rates were significantly higher among both males and females in lower education groups [11]. Cancer mortality rates were also higher among males with lower education level in Madrid, Basque region, Barcelona, Turin, and Slovenia [11, 56]. Another study found higher total cancer mortality rates especially among men in more deprived neighborhoods of several Spanish cities, including Barcelona, Madrid, Bilbao, Seville, and Valencia [57].

Consistent with the US pattern, lung cancer mortality rates for both men and women in urban Canada and Quebec

increased in relation to deprivation levels [13, 55]. Higher lung cancer mortality rates were found among men in lower SES groups in 16 European populations; however, lung cancer mortality rates were higher among women in higher SES groups in such Southern and Eastern European populations as Turin, Basque, Barcelona, and Slovenia [58]. Another study found an inverse SES gradient in lung cancer mortality for both men and women in several Northern European countries, including Switzerland, Belgium, Denmark, Norway, Sweden, and Finland [11]. Lung cancer mortality rates were higher for men and lower for women in deprived groups compared with affluent groups in several Spanish cities [57].

Our finding regarding higher all-cancer and lung cancer mortality rates in rural areas differs from a UK study that found significantly lower total and lung cancer mortality risks in rural than in urban areas of England during the period 2002–2004 before and after adjustment for deprivation levels [59]. Consistent with our study, excess lung cancer mortality in rural areas was found for Australia during 1997–1999 [60]. All-cancer and lung cancer mortality rates for Canadian men and women during the period 1986–1996 were lower in rural than in urban areas [60]. In many European countries (such as Denmark, Spain, Germany, and Italy) that have relatively high lung cancer mortality rates, smoking prevalence tends to be higher in urban than in rural areas, which may imply significantly higher lung cancer mortality risks among their urban residents [61].

This study has some limitations. Area-based socioeconomic disparities in cancer mortality documented here should not be considered as proxies for socioeconomic differentials at the individual level. Such consideration may lead to the ecological fallacy [3–5, 9]. In our study, county-level variations in cancer mortality rates were analyzed as a function of two population-based ecologic variables, the deprivation index and rural-urban continuum. Although area-based socioeconomic patterns in cancer mortality shown are generally consistent with those at the individual level, the area-level effects shown here may be smaller in magnitude than individual-level SES effects [5–8, 10–12]. This may partly be due to the compositional heterogeneity of the counties examined, which are socioeconomically more heterogeneous than census tracts [3–5]. Because of the lack of census-tract geocodes, it is not possible to analyze national mortality data at a geographic level smaller than county [5, 25–27]. Although we conducted separate analyses for whites and blacks, we did not examine cancer mortality patterns for the other major racial/ethnic groups in the US, including Asians/Pacific Islanders, American Indians/Alaska Natives, and Hispanics.

Cancer is the leading cause of mortality in the US for those aged <85 years and is the most prominent cause of death in terms of years of potential life lost [15, 19]. The extent of social disparities in cancer mortality reported here contributes greatly to overall health inequalities in the US. With large socioeconomic inequalities in smoking among young people continuing to persist, inequalities in lung and all-cancer mortality in the US are not expected to diminish in the foreseeable future. Currently, men and women in low- and middle-SES categories have a higher smoking prevalence

than the Healthy People 2010 goal of 12% [62]. Efforts to reduce cancer mortality disparities especially those in lung cancer therefore might include tobacco control policies at the national and local levels that place greater smoking restrictions or legislate against smoking in public places, ban tobacco marketing, reduce tobacco availability, increase financial and other barriers to smoking, and provide targeted smoking cessation programs for those with low SES or in disadvantaged areas [5, 35, 58, 63]. Moreover, healthcare inequalities in the US have also risen in both absolute and relative terms and socioeconomic disparities in stage at diagnosis and survival from major cancers have persisted [5, 15]. These trends would also imply continuation of social inequalities in cancer mortality. Health policies therefore should also enhance access to cancer screening programs among socioeconomically disadvantaged populations or those in rural and medically underserved areas. Lastly, social policy measures aimed at improving the broader social determinants, such as general living conditions and social and physical environments, are needed to tackle health inequalities, including those in cancer mortality [64].

1.5. Conclusions. Socioeconomic deprivation and rural-urban continuum were both independently related to US cancer mortality disparities, with higher all-cancer and lung cancer mortality rates generally found in more deprived groups and rural areas. Socioeconomic inequalities existed for both whites and blacks, and the impact of deprivation on cancer mortality was considerably greater than that of urbanization. Inequalities in lung cancer mortality were particularly marked. Socioeconomic gradients in cancer mortality were steeper in nonmetropolitan than in metropolitan areas. Social inequalities in cancer mortality may be associated with similar disparities in smoking, other cancer-risk factors, cancer screening, and treatment.

2. Part II

2.1. Introduction. Reduction of health inequalities, including those in cancer incidence, mortality, and survival, continues to be a major goal in the newly released Healthy People 2020 objectives for the United States [65]. In Part I, we analyzed contemporary socioeconomic, rural-urban, and racial disparities in US all-cancer and lung cancer mortality. Although lung cancer is the leading cause of cancer mortality, colorectal, prostate, and breast cancers are among the most commonly diagnosed cancers and these sites, along with cervical cancer, contribute greatly to the overall cancer burden in the United States [15, 20–22].

Association between socioeconomic status (SES) and mortality varies for specific cancers [4–13, 66, 67]. Recent data indicate that SES is inversely related to cervical and colorectal cancer mortality and generally positively related to breast and prostate cancer mortality [4–6, 9–14, 66, 67]. The major behavioral determinants of these cancers, such as diet, alcohol use, obesity, physical inactivity, reproductive behavior, occupational and environmental exposures, and cancer screening, are themselves influenced by socioeconomic factors [5, 15–18].

Analyzing contemporary social inequalities in cancer mortality is central to cancer surveillance research for understanding the extent of cancer-related health inequalities and for developing and implementing effective population-based strategies for cancer prevention and control [5]. Such an analysis may also provide clues to changes in social patterning of cancer mortality as socioeconomic, urbanization, and racial/ethnic patterns in major cancer risk factors, such as smoking, diet, obesity, and physical inactivity change over time [5, 15].

Many studies have examined individual- or area-based socioeconomic disparities in US mortality from colorectal, prostate, breast, and cervical cancers [4, 5, 9, 10, 12, 14, 66]. However, inequalities in mortality from these cancers according to levels of urbanization or rurality have received little or no attention. Furthermore, it is not known to what extent rural and urban areas of the US would differ in site-specific cancer mortality rates after controlling for socioeconomic differences.

In Part II of this paper, we use an area-based socioeconomic deprivation index and a rural-urban continuum variable to examine (1) the most current socioeconomic and rural-urban disparities in US mortality from four major cancers: colon/rectum, breast, prostate, and uterine cervix, (2) whether patterns differ for whites and blacks, and (3) the relative importance of deprivation and rural-urban residence in explaining geographic disparities in cancer mortality rates. These major cancers are not only among the most commonly diagnosed cancers, but they are also leading causes of cancer mortality in the United States [15, 20–22]. Taken together, these four cancers account for nearly a quarter of all cancer deaths and 40% of new cancer cases in the US [20–22]. These are also the cancers for which established screening tests have been introduced into the general population [5, 21].

2.2. Methods. To analyze social inequalities in site-specific cancer mortality, we used three national data sources: the national mortality database, the decennial census, and the 2009–2010 Area Resource File [15, 19, 23, 24]. Area socioeconomic patterns in mortality were derived by linking a county-level socioeconomic deprivation index with the national mortality statistics, as described in Part I and elsewhere [3, 4, 25].

To analyze socioeconomic disparities in mortality rates, we used the weighted population distribution of the deprivation index that classified all 3,141 US counties into 10 groups of approximately equal population size [25]. The groups ranged from being the most deprived (first decile) to the least disadvantaged (tenth decile) population groups [25]. Each of the 3,141 counties in the mortality database was assigned one of the 10 deprivation categories [25]. To simplify analysis and data presentation, we combined the 4th through 7th deciles of the deprivation index since mortality rates did not vary greatly among these middle-deprivation categories.

Rural-urban disparities in mortality were analyzed by using a 9-category rural-urban continuum variable linked to county-level mortality data [24, 28]. To compute mortality rates, we combined the 9 rural-urban categories into 5 groups: large metropolitan county group, medium

metropolitan county group, small metropolitan county group, urban nonmetropolitan county group, and rural nonmetropolitan county group.

Age-sex-race-county-specific population estimates from 2003 to 2007 served as denominators for computing average annual mortality rates [15, 19, 20]. During 2003–2007, the number of site-specific cancer deaths were as follows: 268,783 (colorectal), 144,926 (prostate), 206,983 (breast), and 19,690 (cervical). Mortality rates for each county, area-socioeconomic group, or rural-urban continuum category were age adjusted by the direct method using the age composition of the 2000 US population as the standard and age-specific mortality rates for 19 age groups: <1, 1–4, 5–9, 10–14, . . . , 80–84, 85+ years [5, 19, 20].

Weighted least squares regression models were fitted to county-level age-adjusted cancer mortality rates to estimate socioeconomic and rural-urban gradients in site-specific cancer mortality for the 2003–2007 period and to assess their relative impacts. The effects of both categorical and continuous measures of the deprivation index and rural-urban continuum were estimated in the regression models.

Socioeconomic and rural-urban disparities in mortality, estimated separately for whites and blacks, were described by rate ratios (relative risks) and rate differences (absolute inequalities), which were tested for statistical significance at the 0.05 level. In all regression models, the highest SES group and the most-urbanized-county group (large metro counties) were selected as reference categories. Bivariate and multivariate least squares regression models were estimated by the SAS REG procedure [29].

2.3. Results

2.3.1. Disparities in Colorectal Cancer Mortality. Higher socioeconomic deprivation levels were consistently related to increased colorectal cancer mortality rates among both men and women. Men and women in the two most-deprived groups had 25% and 15% higher risks of colorectal cancer mortality than their most-affluent counterparts, respectively (Table 5). Geographical distribution in colorectal cancer mortality and deprivation was moderately correlated (weighted correlation = 0.37), with those in the Southeastern region having higher mortality rates (Figure 4).

Colorectal cancer mortality rates were 8% higher in nonmetropolitan or rural areas than in the most-urbanized areas containing large metropolitan counties. In the multivariate models, both deprivation and rural-urban residence contributed independently and significantly to disparities in male and female colorectal cancer mortality, with the impact of deprivation on mortality being substantially greater than that of rural-urban residence (Tables 6 and 7).

Socioeconomic gradients and absolute inequalities in colorectal cancer mortality were more pronounced in nonmetropolitan than in metropolitan areas (Table 8). In nonmetropolitan areas, those in the most-deprived group had 39% higher colorectal cancer mortality compared to their most-affluent counterparts. The corresponding relative risk in metropolitan areas was 1.13. For both whites and blacks, the inverse socioeconomic gradients (regression slopes) in

colorectal cancer mortality were steeper in nonmetropolitan than in metropolitan areas (Table 9).

2.3.2. Disparities in Prostate Cancer Mortality. Men in more deprived groups and in rural areas had significantly higher prostate cancer mortality rates than their more affluent and urbanized counterparts, respectively (Table 5). This pattern held especially among black men, who had 26% higher prostate cancer mortality in the most-deprived group than in the least-deprived group and 22% higher mortality in rural areas than in the most-urbanized area.

Geographic patterns in prostate cancer mortality corresponded somewhat with those in deprivation (weighted correlation = 0.28), with the highest mortality rates and deprivation levels observed in the Southeastern region (Figure 4). For the total population, although both deprivation and rural-urban residence contributed independently to area variations in prostate cancer mortality, deprivation had a 4.4 times stronger impact than rural-urban continuum (as evidenced by comparing β 's in the multivariate model of Table 7). In the adjusted models, higher prostate cancer mortality rates were associated with higher deprivation levels among black men and higher levels of rurality among white men (Tables 6 and 7). Inverse socioeconomic gradients in prostate cancer mortality among all men and among white and black men were steeper in nonmetropolitan than in metropolitan areas (Tables 8 and 9).

2.3.3. Disparities in Breast Cancer Mortality. Overall, breast cancer mortality rates did not vary much by deprivation levels; however, women in the most-deprived group had 4% higher mortality compared to their most-affluent counterparts. Socioeconomic patterns in breast cancer mortality differed by race. White women had 4% lower breast cancer mortality in the most-deprived group than in the least-deprived group, whereas black women had 11% higher breast cancer mortality in the most-deprived group than in the least-deprived group (Table 5).

Geographical distribution of breast cancer mortality does not quite correspond with that of deprivation levels, with women in the Northeast region having higher mortality rates than those in the other regions of the US (see Figure 5). After controlling for rural-urban residence, higher deprivation levels were associated with higher breast cancer mortality rates for the total population and for black women; however, socioeconomic disparities were not statistically significant for white women (Tables 6 and 7). After adjusting for SES, white women in rural areas had significantly higher breast cancer mortality rates than their urban counterparts.

Relative and absolute socioeconomic disparities in breast cancer mortality were substantially more marked in nonmetropolitan than in metropolitan areas. Breast cancer mortality in metropolitan areas was 4% higher in the most-deprived group than in the least-deprived group, whereas breast cancer mortality in nonmetropolitan areas was 39% higher among women in the most-deprived group than in the least-deprived group (Table 8). Socioeconomic gradients in breast cancer mortality among all women and among white

TABLE 5: Age-adjusted colorectal, prostate, breast, and cervical cancer mortality rates per 100,000 population and relative risk (RR) of mortality according to socioeconomic deprivation deciles and five rural-urban categories, United States, 2003–2007.

	Age-adjusted mortality			Age-adjusted mortality			Age-adjusted mortality		
	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR
Colorectal cancer mortality	Total population			All males			All females		
Socioeconomic deprivation index									
Socioeconomic decile 1	19.29	0.11	1.20*	23.70	0.19	1.25*	15.95	0.14	1.15*
Socioeconomic decile 2	19.16	0.11	1.20*	23.47	0.19	1.24*	15.90	0.13	1.15*
Socioeconomic decile 3	18.38	0.11	1.15*	22.51	0.18	1.19*	15.23	0.13	1.10*
Socioeconomic deciles 4–7	17.53	0.05	1.09*	21.04	0.09	1.11*	14.90	0.07	1.08*
Socioeconomic decile 8	16.47	0.10	1.03*	19.34	0.17	1.02*	14.27	0.13	1.03*
Socioeconomic decile 9	16.67	0.11	1.04*	19.76	0.19	1.04*	14.30	0.14	1.03*
Socioeconomic decile 10	16.01	0.10	1.00	18.99	0.18	1.00	13.82	0.13	1.00
Rural-urban continuum category									
Large metro counties	17.48	0.05	1.00	21.00	0.08	1.00	14.90	0.06	1.00
Medium metro counties	16.88	0.07	0.97*	20.19	0.13	0.96*	14.36	0.09	0.96*
Small metro counties	17.36	0.11	0.99	21.14	0.18	1.01	14.46	0.13	0.97*
Urban nonmetro counties	18.91	0.08	1.08*	22.87	0.14	1.09*	15.83	0.10	1.06*
Rural counties	18.82	0.23	1.08*	22.82	0.39	1.09*	15.41	0.28	1.03
Colorectal cancer mortality	All whites			All blacks			Black male		
Socioeconomic deprivation index									
Socioeconomic decile 1	18.41	0.12	1.15*	25.42	0.34	1.14*	31.50	0.62	1.18*
Socioeconomic decile 2	18.48	0.11	1.15*	24.86	0.36	1.11*	31.50	0.68	1.18*
Socioeconomic decile 3	17.99	0.11	1.12*	24.24	0.45	1.09*	30.14	0.81	1.13*
Socioeconomic deciles 4–7	16.89	0.06	1.05*	25.43	0.22	1.14*	31.38	0.39	1.18*
Socioeconomic decile 8	16.04	0.11	1.00	23.63	0.48	1.06	28.40	0.87	1.07
Socioeconomic decile 9	16.55	0.12	1.03*	24.13	0.56	1.08*	29.01	1.02	1.09
Socioeconomic decile 10	16.03	0.11	1.00	22.33	0.56	1.00	26.63	1.01	1.00
Rural-urban continuum category									
Large metro counties	16.83	0.05	1.00	24.80	0.17	1.00	30.62	0.32	1.00
Medium metro counties	16.50	0.08	0.98*	23.87	0.34	0.96*	29.40	0.61	0.96*
Small metro counties	16.88	0.11	1.00	25.22	0.51	1.02	30.83	0.91	1.01*
Urban non-metro counties	18.51	0.09	1.10*	25.95	0.41	1.05*	31.92	0.72	1.04*
Rural counties	18.42	0.24	1.09*	23.96	1.11	0.97*	31.81	2.01	1.04
Prostate cancer mortality	Total population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	27.67	0.22	1.21*	23.42	0.22	1.03*	58.69	0.89	1.26*
Socioeconomic decile 2	25.32	0.20	1.11*	22.16	0.20	0.98	57.91	0.99	1.25*
Socioeconomic decile 3	24.30	0.19	1.06*	22.69	0.19	1.00	50.70	1.13	1.09*
Socioeconomic deciles 4–7	24.69	0.10	1.08*	22.64	0.11	1.00	54.17	0.56	1.17*
Socioeconomic decile 8	24.06	0.20	1.05*	22.88	0.20	1.01	49.54	1.26	1.07
Socioeconomic decile 9	24.22	0.23	1.06*	23.75	0.24	1.05*	52.72	1.54	1.14*
Socioeconomic decile 10	22.88	0.21	1.00	22.70	0.22	1.00	46.40	1.47	1.00
Rural-urban continuum category									
Large metro counties	24.51	0.09	1.00	22.23	0.10	1.00	52.35	0.45	1.00
Medium metro counties	24.36	0.14	0.99	22.70	0.15	1.02*	56.20	0.92	1.07*
Small metro counties	24.81	0.21	1.01	23.34	0.21	1.05*	53.59	1.30	1.02
Urban nonmetro counties	25.51	0.16	1.04*	23.75	0.16	1.07*	60.28	1.06	1.15*
Rural counties	25.86	0.41	1.06*	23.96	0.41	1.08*	63.67	2.94	1.22*
Breast cancer mortality	Total population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	24.50	0.17	1.04*	23.07	0.19	0.96*	32.69	0.50	1.11*
Socioeconomic decile 2	24.44	0.17	1.04*	23.22	0.18	0.97*	32.77	0.53	1.12*

TABLE 5: Continued.

	Age-adjusted mortality			Age-adjusted mortality			Age-adjusted mortality		
	Rate	SE	RR	Rate	SE	RR	Rate	SE	RR
Socioeconomic decile 3	23.84	0.17	1.01	23.05	0.17	0.96*	32.80	0.66	1.12*
Socioeconomic deciles 4–7	24.13	0.09	1.03*	23.37	0.09	0.98*	33.21	0.31	1.13*
Socioeconomic decile 8	24.02	0.17	1.02*	23.76	0.18	0.99	30.96	0.66	1.06
Socioeconomic decile 9	23.27	0.17	0.99	23.52	0.19	0.98	31.35	0.75	1.07
Socioeconomic decile 10	23.53	0.17	1.00	23.94	0.18	1.00	29.33	0.76	1.00
Rural-urban continuum Category									
Large metro counties	24.39	0.08	1.00	23.74	0.08	1.00	32.65	0.24	1.00
Medium metro counties	23.42	0.12	0.96*	23.01	0.13	0.97*	31.34	0.48	0.96*
Small metro counties	23.71	0.17	0.97*	23.20	0.18	0.98*	32.07	0.73	0.98
Urban nonmetro counties	23.67	0.13	0.97*	23.07	0.14	0.97*	33.11	0.60	1.01
Rural counties	23.11	0.37	0.95*	22.18	0.37	0.93*	35.23	1.82	1.08
Cervical cancer mortality	Total Population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	3.54	0.07	2.21*	3.12	0.07	2.07*	5.76	0.21	1.92*
Socioeconomic decile 2	3.01	0.06	1.88*	2.65	0.06	1.75*	5.27	0.21	1.76*
Socioeconomic decile 3	2.67	0.06	1.67*	2.50	0.06	1.66*	4.51	0.24	1.50*
Socioeconomic deciles 4–7	2.44	0.03	1.53*	2.22	0.03	1.47*	4.22	0.11	1.41*
Socioeconomic decile 8	2.09	0.05	1.31*	1.92	0.05	1.27*	3.95	0.24	1.32*
Socioeconomic decile 9	1.82	0.05	1.14*	1.71	0.05	1.13*	3.22	0.24	1.07
Socioeconomic decile 10	1.60	0.04	1.00	1.51	0.05	1.00	3.00	0.24	1.00
Rural-urban continuum category									
Large metro counties	2.39	0.02	1.00	2.12	0.03	1.00	4.22	0.09	1.00
Medium metro counties	2.25	0.04	0.94*	2.09	0.04	0.99	4.01	0.17	0.95
Small metro counties	2.46	0.06	1.03	2.27	0.06	1.07*	4.80	0.28	1.14*
Urban nonmetro counties	2.79	0.05	1.17*	2.55	0.05	1.20*	6.01	0.26	1.42*
Rural counties	2.69	0.14	1.13*	2.46	0.14	1.16*	4.89	0.70	1.16

Mortality rates are age adjusted to the 2000 US standard population. * $P < 0.05$.

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

For computing relative risks of cancer mortality, the tenth socioeconomic decile and large metro counties were treated as reference categories.

¹Counties in metropolitan areas with 1 million population or more. ²Counties in metropolitan areas of 250,000–1,000,000 population.

³Counties in metropolitan areas with population <250,000. ⁴Urban nonmetro counties. ⁵Rural counties with no places with a population of 2,500+.

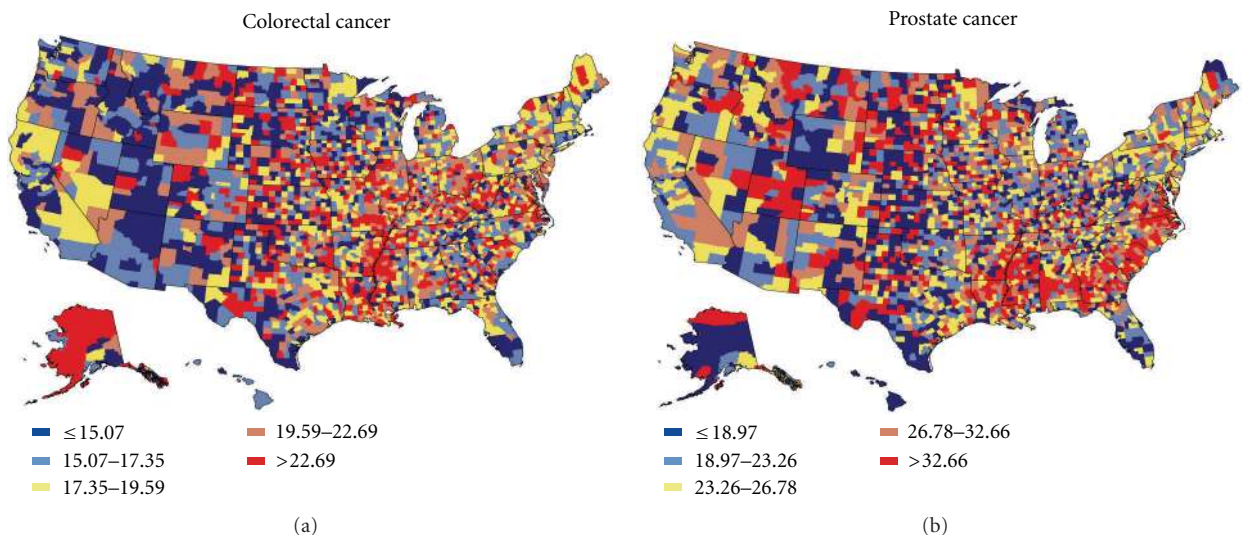


FIGURE 4: Colorectal and prostate cancer mortality rates per 100,000 population (age adjusted to the 2000 population), United States, 2003–2007 (3,141 counties).

TABLE 6: Multivariate weighted least squares regression models showing adjusted differentials in colorectal, prostate, breast, and cervical cancer mortality rates per 100,000 population according to socioeconomic deprivation deciles and five rural-urban categories, United States, 2003–2007.

	Predicted mortality rate			Predicted mortality rate			Predicted mortality rate		
	Mean	SE	<i>P</i> value	Mean	SE	<i>P</i> value	Mean	SE	<i>P</i> value
Colorectal cancer mortality	Total population			All males			All females		
Socioeconomic deprivation index									
Socioeconomic decile 1	20.46	0.18	<0.001	25.88	0.28	<0.001	17.77	0.20	<0.001
Socioeconomic decile 2	19.93	0.17	<0.001	25.11	0.27	<0.001	17.06	0.19	<0.001
Socioeconomic decile 3	19.11	0.18	<0.001	24.07	0.28	<0.001	16.33	0.19	<0.001
Socioeconomic deciles 4–7	18.11	0.12	<0.001	22.20	0.19	<0.001	15.86	0.14	<0.001
Socioeconomic decile 8	17.28	0.20	<0.001	20.86	0.32	0.002	15.34	0.22	0.006
Socioeconomic decile 9	17.15	0.22	0.064	20.71	0.35	0.009	15.17	0.24	0.036
Socioeconomic decile 10	16.27	0.22	Reference	19.59	0.35	Reference	14.56	0.24	Reference
Rural-urban continuum category									
Large metro counties	18.51	0.09	Reference	22.46	0.14	Reference	15.81	0.10	Reference
Medium metro counties	17.61	0.13	<0.001	21.25	0.21	<0.001	15.20	0.15	<0.001
Small metro counties	17.52	0.18	<0.001	21.43	0.29	0.001	15.02	0.20	<0.001
Urban nonmetro counties	18.68	0.15	0.323	22.72	0.23	0.368	16.37	0.16	0.004
Rural counties	19.32	0.37	0.034	25.29	0.56	<0.001	17.65	0.41	<0.001
Colorectal cancer mortality	All whites			All blacks			Black male		
Socioeconomic deprivation index									
Socioeconomic decile 1	19.51	0.18	<0.001	24.84	0.52	<0.001	31.08	1.50	0.031
Socioeconomic decile 2	19.34	0.17	<0.001	24.11	0.58	0.002	30.68	1.66	0.035
Socioeconomic decile 3	18.82	0.17	<0.001	23.64	0.66	0.020	29.56	1.88	0.129
Socioeconomic deciles 4–7	17.80	0.12	<0.001	24.96	0.48	<0.001	31.19	1.37	0.007
Socioeconomic decile 8	17.34	0.20	0.066	23.52	0.69	0.023	27.95	1.97	0.356
Socioeconomic decile 9	17.42	0.22	0.037	23.36	0.73	0.041	28.25	2.08	0.309
Socioeconomic decile 10	16.86	0.22	Reference	21.59	0.78	Reference	25.71	2.24	Reference
Rural-urban continuum category									
Large metro counties	17.78	0.09	Reference	24.44	0.24	Reference	29.88	0.69	Reference
Medium metro counties	17.32	0.13	0.003	22.81	0.43	<0.001	27.57	1.24	0.081
Small metro counties	17.30	0.18	0.016	24.24	0.63	0.764	28.93	1.80	0.624
Urban nonmetro counties	18.76	0.14	<0.001	24.52	0.61	0.905	30.17	1.72	0.874
Rural counties	19.61	0.35	<0.001	22.58	1.68	0.277	29.46	4.73	0.932
Prostate cancer mortality	Total population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	31.24	0.37	<0.001	25.61	0.32	0.927	57.80	1.49	<0.001
Socioeconomic decile 2	27.59	0.37	<0.001	24.19	0.31	0.002	58.43	1.66	<0.001
Socioeconomic decile 3	25.99	0.37	<0.001	24.65	0.30	0.029	53.43	1.87	0.044
Socioeconomic deciles 4–7	26.21	0.25	<0.001	25.10	0.21	0.128	55.45	1.36	<0.001
Socioeconomic decile 8	25.63	0.42	<0.001	25.91	0.34	0.559	51.81	1.96	0.151
Socioeconomic decile 9	25.35	0.46	0.003	26.50	0.37	0.067	54.55	2.07	0.013
Socioeconomic decile 10	23.60	0.47	Reference	25.63	0.38	Reference	48.35	2.23	Reference
Rural-urban continuum category									
Large metro counties	26.18	0.19	Reference	22.82	0.17	Reference	51.83	0.68	Reference
Medium metro counties	25.81	0.28	0.240	23.75	0.23	<0.001	53.97	1.23	0.104
Small metro counties	25.55	0.38	0.132	24.73	0.30	<0.001	51.57	1.79	0.891
Urban nonmetro counties	26.27	0.30	0.810	26.13	0.24	<0.001	56.21	1.71	0.020
Rural counties	28.77	0.74	<0.001	29.42	0.59	<0.001	57.72	4.70	0.218

TABLE 6: Continued.

	Predicted mortality rate			Predicted mortality rate			Predicted mortality rate		
	Mean	SE	P value	Mean	SE	P value	Mean	SE	P value
Breast cancer mortality	Total population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	26.40	0.24	<0.001	24.88	0.24	0.304	32.43	0.92	0.037
Socioeconomic decile 2	25.62	0.24	<0.001	24.60	0.23	0.816	32.95	1.03	0.010
Socioeconomic decile 3	24.87	0.24	<0.001	24.23	0.22	0.369	32.92	1.17	0.018
Socioeconomic deciles 4–7	24.53	0.17	<0.001	24.19	0.16	0.179	33.21	0.85	0.001
Socioeconomic decile 8	24.37	0.26	0.003	24.68	0.25	0.590	30.87	1.21	0.280
Socioeconomic decile 9	23.47	0.28	0.862	24.13	0.27	0.211	31.04	1.28	0.244
Socioeconomic decile 10	23.41	0.28	Reference	24.52	0.26	Reference	29.28	1.37	References
Rural-urban continuum category									
Large metro counties	25.23	0.12	Reference	24.28	0.12	Reference	32.12	0.41	Reference
Medium metro counties	24.04	0.17	<0.001	23.67	0.16	0.001	30.12	0.75	0.013
Small metro counties	24.11	0.24	<0.001	24.05	0.22	0.355	30.74	1.12	0.245
Urban nonmetro counties	24.24	0.20	<0.001	24.44	0.18	0.481	32.45	1.09	0.781
Rural counties	25.72	0.51	0.362	25.86	0.48	0.002	33.65	3.01	0.616
Cervical cancer mortality	Total population			White			Black		
Socioeconomic deprivation index									
Socioeconomic decile 1	5.22	0.10	<0.001	5.06	0.11	<0.001	5.42	0.32	<0.001
Socioeconomic decile 2	4.37	0.10	<0.001	4.15	0.11	<0.001	5.38	0.35	<0.001
Socioeconomic decile 3	3.91	0.11	<0.001	3.83	0.11	<0.001	4.65	0.40	0.002
Socioeconomic deciles 4–7	3.45	0.08	<0.001	3.33	0.08	<0.001	4.38	0.29	0.001
Socioeconomic decile 8	3.03	0.13	<0.001	2.97	0.14	0.003	4.11	0.42	0.031
Socioeconomic decile 9	2.70	0.14	0.065	2.77	0.15	0.081	3.44	0.44	0.404
Socioeconomic decile 10	2.38	0.14	Reference	2.44	0.15	Reference	3.01	0.47	Reference
Rural-urban continuum category									
Large metro counties	2.97	0.05	Reference	2.74	0.06	Reference	4.27	0.14	Reference
Medium metro counties	2.61	0.08	<0.001	2.49	0.09	0.014	3.88	0.26	0.151
Small metro counties	2.84	0.11	0.265	2.75	0.12	0.922	4.26	0.39	0.972
Urban nonmetro counties	3.34	0.09	<0.001	3.38	0.09	<0.001	5.22	0.38	0.022
Rural counties	6.14	0.24	<0.001	6.18	0.25	<0.001	4.09	1.04	0.860

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

and black women were steeper in nonmetropolitan than in metropolitan areas (Tables 8 and 9).

2.3.4. Disparities in Cervical Cancer Mortality. Cervical cancer mortality rates increased consistently in relation to increasing deprivation levels, with women in the most-deprived group having 2.2 times higher mortality than women in the least-deprived group (Table 5). Socioeconomic gradients were consistent and similarly marked for both white and black women (Table 5). Women in the two most-rural county groups had 13–17% higher cervical cancer mortality than women in the most-urbanized areas (Table 5). Both white women and black women in nonmetropolitan or rural areas had higher cervical cancer mortality rates than their most-urbanized counterparts (Table 5).

Geographical distributions of cervical cancer mortality and deprivation correspond quite closely (weighted correlation = 0.50), with both mortality and deprivation levels being

substantially higher in the Southeastern and Southwestern regions than elsewhere in the US (Figure 5). Deprivation and urbanization level were strongly and independently associated with cervical cancer mortality (Tables 6 and 7). Regardless of rural-urban residence, women in the most-deprived group had 2.2 times higher cervical cancer mortality than women in the least-deprived group (the expected mortality rate/100,000 population 5.22 versus 2.38). After adjusting for SES, women in the most-rural areas had a 2.1 times higher cervical cancer mortality rate than women in the most-urbanized areas (6.14 versus 2.97) (Table 6). The impact of deprivation on cervical cancer mortality was stronger than rural-urban continuum. The deprivation index and rural-urban continuum jointly accounted for 28.5% of the variance in cervical cancer mortality rates (Table 7).

Adjusted socioeconomic and rural-urban disparities in cervical cancer mortality among white women were similar to those for the total population. However, in the adjusted

TABLE 7: Weighted least squares regression models¹ showing the relative impacts of the continuous socioeconomic deprivation index² and rural-urban continuum³ on county-level age-adjusted mortality rates for colorectal, prostate, breast, and cervical cancers, United States, 2003–2007 ($N = 3141$).

Covariate	Bivariate models					Multivariate models				
	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. R^2	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. R^2
Colorectal cancer mortality—total population										
Socioeconomic deprivation index	−0.064	−0.371	−22.29	<0.001	13.75	−0.058	−0.339	−16.93	<0.001	13.95
Rural-urban continuum	0.419	0.247	14.18	<0.001	6.05	0.098	0.058	2.88	0.004	
Colorectal cancer mortality—male										
Socioeconomic deprivation index	−0.101	−0.377	−22.56	<0.001	14.21	−0.088	−0.328	−16.31	<0.001	14.72
Rural-urban continuum	0.720	0.272	15.62	<0.001	7.34	0.233	0.088	4.37	<0.001	
Colorectal cancer mortality—female										
Socioeconomic deprivation index	−0.053	−0.294	−17.01	<0.001	8.63	−0.041	−0.231	−11.18	<0.001	9.49
Rural-urban continuum	0.431	0.242	13.76	<0.001	5.81	0.202	0.113	5.47	<0.001	
Colorectal cancer mortality—white										
Socioeconomic deprivation index	−0.052	−0.307	−17.95	<0.001	9.41	−0.035	−0.208	−10.08	<0.001	11.44
Rural-urban continuum	0.480	0.293	17.04	<0.001	8.56	0.286	0.175	8.49	<0.001	
Colorectal cancer mortality—white male										
Socioeconomic deprivation index	−0.090	−0.325	−18.97	<0.001	10.55	−0.063	−0.227	−11.01	<0.001	12.50
Rural-urban continuum	0.799	0.301	17.42	<0.001	9.04	0.455	0.171	8.30	<0.001	
Colorectal cancer mortality—white female										
Socioeconomic deprivation index	−0.042	−0.233	−17.01	<0.001	5.40	−0.019	−0.105	−4.99	<0.001	8.80
Rural-urban continuum	0.500	0.285	16.35	<0.001	8.08	0.395	0.225	10.66	<0.001	
Colorectal cancer mortality—black										
Socioeconomic deprivation index	−0.041	−0.084	−4.71	<0.001	0.68	−0.056	−0.116	−5.41	<0.001	0.88
Rural-urban continuum	0.038	0.006	0.35	0.725	0.00	−0.343	−0.057	−2.68	0.007	
Colorectal cancer mortality—black male										
Socioeconomic deprivation index	−0.070	−0.051	−2.84	0.005	0.23	−0.090	−0.065	−3.03	0.003	0.24
Rural-urban continuum	0.172	0.010	0.57	0.569	0.01	−0.436	−0.026	−1.20	0.229	
Colorectal cancer mortality—black female										
Socioeconomic deprivation index	−0.026	−0.042	−2.33	0.020	0.14	−0.037	−0.061	−2.83	0.005	0.19
Rural-urban continuum	−0.009	−0.001	−0.06	0.951	0.00	−0.265	−0.034	−1.60	0.110	
Prostate cancer mortality—total population										
Socioeconomic deprivation index	−0.098	−0.283	−16.37	<0.001	8.00	−0.087	−0.252	−12.12	<0.001	8.20
Rural-urban continuum	0.665	0.197	11.11	<0.001	3.83	0.194	0.057	2.77	<0.001	
Prostate cancer mortality—white										
Socioeconomic deprivation index	−0.028	−0.097	−5.41	0.009	0.92	0.022	0.078	3.69	<0.001	7.46
Rural-urban continuum	0.721	0.267	15.28	<0.001	7.07	0.840	0.310	14.72	<0.001	
Prostate cancer mortality—black										
Socioeconomic deprivation index	−0.170	−0.124	−6.91	<0.001	1.49	−0.149	−0.108	−5.03	<0.001	1.52
Rural-urban continuum	1.473	0.088	4.89	<0.001	0.74	0.467	0.028	1.30	0.195	
Breast cancer mortality—total population										
Socioeconomic deprivation index	−0.034	−0.164	−9.22	<0.001	2.65	−0.038	−0.186	−8.80	<0.001	2.74
Rural-urban continuum	0.130	0.060	3.36	<0.001	0.33	−0.089	−0.041	−1.95	0.051	
Breast cancer mortality—white										
Socioeconomic deprivation index	−0.008	−0.039	−2.17	0.030	0.12	0.001	0.005	0.22	0.822	0.52
Rural-urban continuum	0.151	0.076	4.23	<0.001	0.55	0.157	0.079	3.63	<0.001	

TABLE 7: Continued.

Covariate	Bivariate models					Multivariate models				
	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. <i>R</i> ²	<i>b</i>	β	<i>t</i> -stat.	<i>P</i> value	Adj. <i>R</i> ²
Breast cancer mortality—black										
Socioeconomic deprivation index	−0.048	−0.057	−3.18	0.002	0.30	−0.060	−0.071	−3.31	<0.001	0.31
Rural-urban continuum	0.142	0.013	0.75	0.455	0.00	−0.268	−0.025	−1.19	0.236	
Cervical cancer mortality—total population										
Socioeconomic deprivation index	−0.048	−0.503	−28.11	<0.001	25.28	−0.037	−0.385	−18.37	<0.001	28.53
Rural-urban continuum	0.426	0.427	22.81	<0.001	18.21	0.216	0.216	10.34	<0.001	
Cervical cancer mortality—white										
Socioeconomic deprivation index	−0.048	−0.470	−24.94	<0.001	22.07	−0.032	−0.316	−14.45	<0.001	27.45
Rural-urban continuum	0.465	0.454	23.85	<0.001	20.58	0.286	0.279	12.79	<0.001	
Cervical cancer mortality—black										
Socioeconomic deprivation index	−0.043	−0.149	−8.35	<0.001	2.19	−0.041	−0.141	−6.60	<0.001	2.17
Rural-urban continuum	0.337	0.092	5.12	<0.001	0.81	0.055	0.015	0.70	0.481	

Notes: *b*: unstandardized regression coefficient; β : standardized regression coefficient; *R*²: percentage variance explained.

β is also equal to the correlation coefficient in bivariate regression models.

¹The least squares regression models are weighted, with weights being cancer-specific deaths in each county.

²The 2000 census socioeconomic deprivation index is a continuous variable with a mean of 100 and a standard deviation of 20.

Higher index scores denote higher levels of socioeconomic position and lower levels of deprivation.

³The 2003 rural-urban continuum is used as a continuous variable, with code 1 being the most urbanized county and code 9 being the most rural county.

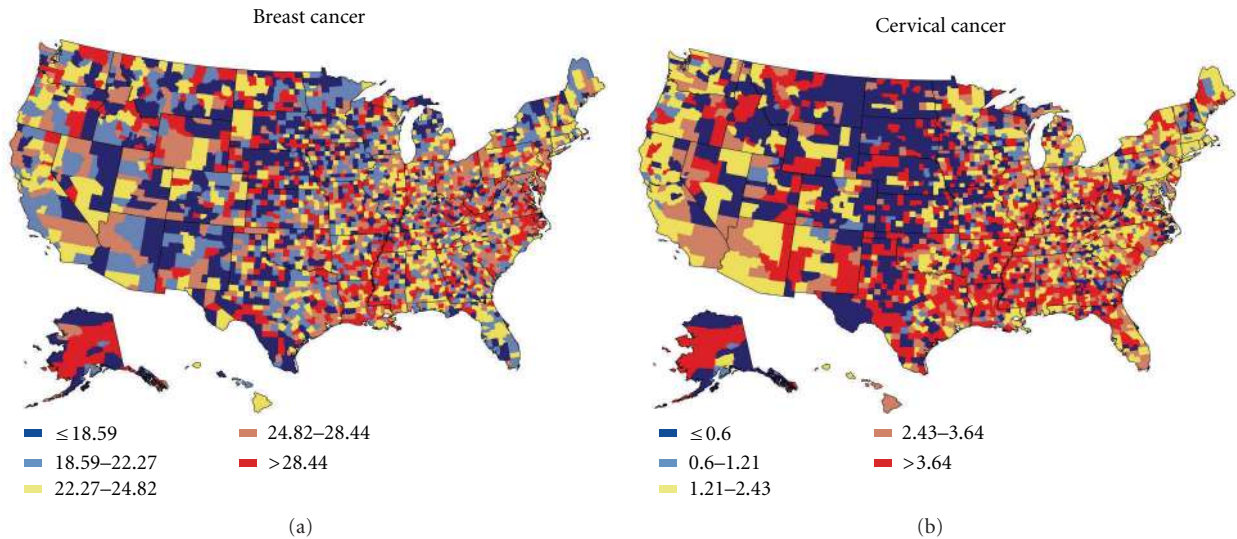


FIGURE 5: Breast and cervical cancer mortality rates per 100,000 population (age adjusted to the 2000 population), United States, 2003–2007 (3,141 Counties).

models for black women, only socioeconomic disparities in cervical cancer mortality were marked, with rural-urban differences being not statistically significant (Tables 6 and 7). Relative and absolute socioeconomic disparities in cervical cancer mortality were larger among all women and white women in nonmetropolitan than in metropolitan areas (Tables 8 and 9). Deprivation was related to cervical cancer mortality among black women only in metropolitan areas (Table 9).

2.4. Discussion. In Part II of this study, we used a composite area-based deprivation index and a rural-urban continuum

measure to analyze socioeconomic, rural-urban, and racial disparities in US mortality from colorectal, prostate, breast, and cervical cancers. As far as we are aware, our study is the first to examine the independent and joint effects of deprivation and urbanization on US mortality from these cancers.

SES, race, and urbanization have long been considered important axes of health and social stratification in the United States [15, 65]. Inequalities in mortality from various cancers according to these social characteristics are rarely analyzed simultaneously. Our study showing substantial SES and urbanization differences in mortality from major

TABLE 8: Socioeconomic disparities in colorectal, prostate, breast, and cervical cancer mortality rates per 100,000 population, relative risks (RRs), and gradients in mortality within metropolitan and nonmetropolitan areas of the United States, 2003–2007.

	Metropolitan areas			Nonmetropolitan areas		
	Rate	SE	RR	Rate	SE	RR
<i>Colorectal cancer mortality</i>						
Socioeconomic deprivation index						
Socioeconomic decile 1	18.06	0.18	1.13*	20.01	0.14	1.39*
Socioeconomic decile 2	19.16	0.15	1.20*	19.14	0.16	1.33*
Socioeconomic decile 3	18.29	0.13	1.14*	18.48	0.18	1.28
Socioeconomic deciles 4–7	17.52	0.06	1.09*	17.57	0.17	1.22
Socioeconomic decile 8	16.48	0.11	1.03*	16.06	0.54	1.12
Socioeconomic decile 9	16.69	0.11	1.04*	15.28	0.80	1.06
Socioeconomic decile 10	16.02	0.10	1.00	14.39	1.77	1.00
Deprivation gradient ¹	−0.050*	0.005 ²		−0.079*	0.006	
<i>Prostate cancer mortality</i>						
Socioeconomic deprivation index						
Socioeconomic decile 1	26.95	0.36	1.18*	28.06	0.27	1.20*
Socioeconomic decile 2	26.17	0.28	1.14*	24.42	0.28	1.04*
Socioeconomic decile 3	23.97	0.24	1.05*	24.86	0.33	1.06*
Socioeconomic deciles 4–7	24.76	0.11	1.08*	24.02	0.32	1.02
Socioeconomic decile 8	24.12	0.20	1.05*	22.85	1.02	0.97
Socioeconomic decile 9	24.21	0.23	1.06*	24.55	1.60	1.05
Socioeconomic decile 10	22.88	0.21	1.00	23.48	3.67	1.00
Deprivation gradient	−0.072*	0.009		−0.178*	0.012	
<i>Breast cancer mortality</i>						
Socioeconomic deprivation index						
Socioeconomic decile 1	24.41	0.28	1.04*	24.58	0.22	1.39*
Socioeconomic decile 2	24.85	0.23	1.06*	23.85	0.25	1.35*
Socioeconomic decile 3	24.32	0.20	1.03*	22.76	0.28	1.29
Socioeconomic deciles 4–7	24.26	0.09	1.03*	22.71	0.27	1.29
Socioeconomic decile 8	24.09	0.17	1.02*	21.94	0.86	1.24
Socioeconomic decile 9	23.29	0.18	0.99	22.35	1.33	1.26
Socioeconomic decile 10	23.55	0.17	1.00	17.67	2.34	1.00
Deprivation gradient	−0.028*	0.005		−0.079*	0.008	
<i>Cervical cancer mortality</i>						
Socioeconomic deprivation index						
Socioeconomic decile 1	3.60	0.11	2.11*	3.50	0.09	3.40*
Socioeconomic decile 2	3.13	0.08	1.83*	2.88	0.09	2.80*
Socioeconomic decile 3	2.83	0.07	1.65*	2.33	0.10	2.26*
Socioeconomic deciles 4–7	2.48	0.03	1.45*	2.04	0.09	1.98*
Socioeconomic decile 8	2.10	0.05	1.23*	1.78	0.25	1.73
Socioeconomic decile 9–10	1.71	0.03	1.00	1.03	0.25	1.00
Deprivation gradient	−0.037*	0.002		−0.060*	0.005	

Metropolitan areas consist of large metro counties with population ≥ 1 million and smaller metro counties of population $< 250,000$.

Nonmetropolitan areas consist of small urban towns with a population $< 20,000$ and rural towns with a population $< 2,500$.

Mortality rates are age adjusted to the 2000 US standard population. * $P < 0.05$.

Decile 1 of the socioeconomic deprivation index represents the most deprived group and decile 10 the least deprived group.

For computing relative risks of cancer mortality, the tenth socioeconomic decile was treated as the reference category.

¹Measured by the slope or unstandardized regression coefficient associated with the continuous deprivation index. ²Standard error of slope.

TABLE 9: Race-specific socioeconomic disparities in colorectal, prostate, breast, and cervical cancer mortality rates per 100,000 population, relative risks (RRs), and gradients in mortality within metropolitan and nonmetropolitan areas of the United States, 2003–2007.

	Metropolitan areas								Nonmetropolitan areas					
	SES decile 1		SES decile 10		RR ¹	Deprivation gradient		SES decile 1		SES decile 10 ⁴		RR ¹	Deprivation gradient	
	Rate	SE	Rate	SE		<i>b</i> ²	SE ³	Rate	SE	Rate	SE		<i>b</i> ²	SE ³
Colorectal cancer mortality, total population														
White	16.96	0.20	16.04	0.11	1.06*	−0.030*	0.004	19.19	0.15	14.61	1.84	1.31*	−0.063*	0.006
Black	24.51	0.51	22.34	0.56	1.10*	−0.039*	0.013	26.27	0.46				−0.123*	0.026
Colorectal cancer mortality, male														
White	21.17	0.34	19.12	0.19	1.11*	−0.057*	0.006	23.53	0.26	16.26	3.00	1.45*	−0.109*	0.012
Black	30.20	0.95	26.65	1.01	1.13*	−0.076*	0.025	32.72	0.82				−0.068	0.094
Colorectal cancer mortality, female														
White	13.64	0.24	13.78	0.14	0.99	−0.016*	0.004	15.81	0.19	13.75	2.39	1.15*	−0.057*	0.008
Black	21.21	0.60	19.45	0.66	1.09*	−0.020	0.014	21.89	0.54				−0.120*	0.039
Prostate cancer mortality														
White	22.89	0.37	22.70	0.22	1.01	0.011	0.007	23.70	0.27	23.43	3.75	1.01	−0.033*	0.012
Black	52.79	1.33	46.42	1.47	1.14*	−0.125*	0.037	62.86	1.20				−0.382*	0.074
Breast cancer mortality														
White	23.16	0.31	23.97	0.18	0.97*	0.007	0.005	23.04	0.23	17.46	2.40	1.32*	−0.044*	0.009
Black	31.38	0.73	29.35	0.76	1.07*	−0.045*	0.016	33.91	0.68				−0.118*	0.059
Cervical cancer mortality														
White	3.20	0.12	1.51	0.05	2.12*	−0.032*	0.002	3.07	0.09	1.07	0.26	2.87*	−0.064*	0.006
Black	5.30	0.30	3.00	0.24	1.77*	−0.039*	0.005	6.10	0.29				−0.033	0.021

Metropolitan areas consist of large metro counties with population ≥ 1 million and smaller metro counties of population $< 250,000$.

Nonmetropolitan areas consist of small urban towns with a population $< 20,000$ and rural towns with a population $< 2,500$.

Mortality rates are age adjusted to the 2000 US standard population. * $P < 0.05$.

¹Relative risk is the ratio of the mortality rate for SES decile 1 (the most deprived group) to that for SES decile 10 (the most affluent group).

²Slope or unstandardized regression coefficient associated with the continuous deprivation index. ³Standard error of slope.

⁴Number of deaths was too small (< 5) among nonmetro black men and women in the 10th SES decile to compute reliable mortality rates.

cancers among both US whites and blacks is an important contribution to the literature. Disparities in mortality from these cancers are not just limited to those between low-SES and high-SES or rural and urban groups. Rather, the impact on cancer mortality appears to be graded across the entire range of the socioeconomic hierarchy and rural-urban continuum.

While both socioeconomic deprivation and rural-urban continuum contributed significantly to disparities in mortality from specific cancers, deprivation had a stronger impact and explained larger variance in geographical disparities in mortality. Excess risk of mortality associated with deprivation was particularly marked for cervical, colorectal, and prostate cancers, with the magnitude of disparities generally varying between whites and blacks. Deprivation levels partly accounted for rural-urban disparities in cancer mortality. After adjusting for deprivation, risks of mortality from colorectal, prostate, cervical cancer, and breast cancer in white women were significantly higher in rural than in urban areas.

Socioeconomic trends in US colorectal cancer mortality have changed dramatically over the long term, with the positive SES gradients in mortality narrowing over time and then reversing in the 1990s [4, 5, 14]. A 20% higher mortality risk in the most-deprived group reported in our study seems to indicate the widening of the inverse socioeconomic gradient

in colorectal cancer mortality. Our finding regarding socioeconomic patterns in prostate cancer mortality among all men and black men is consistent with previous research showing higher mortality risks among these populations in more deprived areas [5, 14]. Socioeconomic differences in breast cancer mortality have narrowed over time and reversed in the late 1990s, so that higher deprivation levels are now associated with higher breast cancer mortality rates for the total population and especially for black women [5, 14, 66]. The reversal of the trend has occurred as breast cancer mortality rates have declined over time for more affluent women and increased or remained stable for women in more deprived groups [5]. Despite the fact that cervical cancer mortality rates in the US have declined consistently for the past 6 decades [5, 9, 15, 19], substantial socioeconomic gradients persisted during 2003–2007, with black and white women in the most-deprived groups having a twofold higher mortality risk compared to their most-advantaged counterparts, a pattern that also prevailed in the previous decade [5, 9, 14].

Socioeconomic gradients in colorectal, breast, cervical cancer, and prostate cancer mortality were steeper in nonmetropolitan than in metropolitan areas. A possible reason for the steeper gradients in nonmetropolitan areas is that socioeconomic disparities in cancer risk factors (such as smoking, diet, obesity, and physical inactivity), stage of

diagnosis, patient survival, and healthcare access and utilization may be more marked in rural than urban areas.

Socioeconomic and rural-urban disparities in mortality from various cancers may reflect differences in smoking prevalence, dietary fat intake, obesity, physical inactivity, reproductive factors (e.g., delayed childbearing, childlessness, and breastfeeding), alcohol use, human papillomavirus (HPV) infection, cancer screening, and healthcare factors [4, 5, 11, 15, 18, 33, 68–70]. Smoking has been suggested as a risk factor for colorectal cancer, and higher smoking prevalence in more deprived and rural areas might contribute to inequalities in colorectal cancer mortality [4, 15, 33]. Dietary factors such as fat intake, red meat consumption, and high calorie intake have been mentioned as risk factors for colorectal, prostate, and breast cancer and inequalities in mortality may reflect differences in these factors [4, 5, 18]. Studies have found higher consumption of lower-quality diets and energy-dense foods and lower intakes of fruits and vegetables among lower SES groups but higher total calorie and fat intake among higher SES groups [15, 16, 71, 72]. Alcohol consumption is higher among whites and higher SES groups in the US [15].

Disparities in healthcare factors play a prominent role in producing socioeconomic and rural-urban disparities in mortality from colorectal, prostate, breast, and cervical cancer. Residents of more deprived neighborhoods have been shown to have substantially higher rates of late-stage diagnoses of colorectal, prostate, breast, and cervical cancer and significantly lower rates of cancer survival than their counterparts from more affluent neighborhoods [5, 9, 40–50, 73–75]. Lack of health insurance, limited access to care, and lower rates of regular pap smear, mammography, and colorectal cancer screening among residents of rural and more disadvantaged areas may account for their higher rates of late-stage cancer diagnoses [5, 15, 44–46]. However, lower cancer survival rates among the disadvantaged may not only reflect their higher rates of late-stage cancer diagnoses, but less favorable cancer treatment or medical care may also contribute to their lower survival and higher cancer mortality rates [5, 46].

Deprivation and urbanization levels do not account for racial disparities in site-specific cancer mortality. Within each deprivation group or rural-urban continuum category, black women had approximately two times higher cervical cancer mortality and 50% higher breast cancer mortality than white women. Black men in each deprivation or rural-urban group had at least two times higher prostate cancer mortality rates than their white counterparts. Absolute racial inequalities across deprivation and urbanization categories were equally pronounced, with the mortality rates for blacks in the most-affluent group generally exceeding those for whites in the most-deprived group. As reported in Part I, this may be partly because blacks are socially and materially worse off than whites across different socioeconomic strata. Moreover, they are more likely to be disadvantaged than whites in health-risk behaviors, healthcare access and use, and cancer treatment and survival within each deprivation group.

Detection of cancer at an early, localized stage may be considered a marker for access to healthcare and preventive health services, including cancer screening [5, 21]. Studies have shown significant black-white and socioeconomic disparities in stage at cancer diagnosis. Within each SES/deprivation group, blacks have a higher likelihood than whites of being diagnosed with advanced-stage colorectal, prostate, breast, and cervical cancers. Additionally, even after controlling for stage at diagnosis, blacks, in each deprivation group, have significantly lower survival rates from colorectal, prostate, breast, and cervical cancer than whites [5, 73–75].

Racial/ethnic and socioeconomic disparities in cervical cancer mortality may also be due to differences in HPV infection, the primary cause of cervical cancer [5, 18, 21, 69]. An analysis of the National Health and Nutrition Examination Survey (NHANES) data showed significantly higher HPV prevalence among black and low-SES women [76]. Our analysis of the 2005–2008 NHANES data (not shown here) indicate an HPV prevalence of 57.6% among black women and 38.4% among white women aged 18–59 years [77]. The HPV prevalence ranged from 54.6% for women below the poverty line to 41.1% among those with incomes $\geq 400\%$ of the poverty threshold. Racial disparities persisted even after controlling for SES. For example, in the high-income group, black women had a 47% higher prevalence than their white counterparts (56.9% versus 38.7%). Data on HPV prevalence are not available by rural-urban residence.

Our finding regarding inverse socioeconomic gradients in US colorectal cancer mortality is in line with occupational and educational patterns in mortality observed among several European countries such as France, Sweden, Belgium, and Switzerland [11, 78]. Higher male colorectal cancer mortality was associated with higher deprivation levels in Quebec and Spanish cities of Barcelona and Madrid [55, 57]. Consistent with the pattern for US whites, prostate cancer mortality did not differ by deprivation levels in Quebec [55]. Prostate cancer mortality was, however, higher in more deprived areas in urban Canada [13]. For most of the European populations (except Switzerland and England which had slightly higher mortality in lower SES groups), prostate cancer mortality did not differ significantly by SES [11, 79]. Consistent with the pattern for US whites, breast cancer mortality was lower in more deprived groups in urban Canada and many of the European populations [11, 13].

Marked socioeconomic disparities in US cervical cancer mortality reported here are generally consistent with those shown for other industrialized countries. An approximately twofold higher cervical cancer mortality was found among women in low- than in high-SES groups in a study that compared inequalities in various low-/middle-income countries, North America, and Europe, although the magnitude of socioeconomic inequalities was greater in North America than in Europe [80]. Consistent with our findings, the risk of cervical cancer mortality in Quebec and urban Canada was 1.7 times higher in the poorest neighborhood income quintile than in the richest-income quintile [13, 55, 67]. Two recent studies reported marked educational inequalities

in cervical cancer mortality in many European populations [11, 56].

Colorectal cancer mortality rates were higher in rural than in urban areas of Australia, a finding compatible with the US pattern [60]. However, no significant rural-urban variations in colorectal cancer mortality were found for Canada and England [60, 81]. Like the US pattern, prostate cancer mortality rates were higher in rural than in urban areas of Australia, Canada, and England [60, 81, 82]. Consistent with the US pattern, breast cancer mortality was somewhat lower in rural than in urban areas of Australia and Canada [60]. Consistent with the US pattern, cervical cancer mortality rates were significantly higher in rural than in urban areas of Australia and Canada [60].

This study has some limitations. Area-based socioeconomic disparities in cancer mortality documented here should not be considered as proxies for socioeconomic differentials at the individual level. Such consideration may lead to ecological fallacy [4, 5, 9]. In our study, county-level variations in site-specific cancer mortality rates were analyzed as a function of two population-based ecological variables, the deprivation index and the rural-urban continuum. Although area-based socioeconomic patterns in site-specific cancer mortality shown are generally consistent with those at the individual level, the area-level effects shown here may be smaller in magnitude than individual-level socioeconomic effects [4–12]. Area effects could also be biased if the area SES or rural-urban residence at the time of death differed from that at exposure [5].

The opportunity for reducing social inequalities in cancer mortality exists from a prevention standpoint as social and environmental factors have considerable influence on cancer-related risks such as smoking, obesity, physical inactivity, alcohol consumption, and poor diet. The healthcare system has a special role to play in reducing inequalities from these screenable cancers by helping detect cancers at an early, more treatable stage and providing optimal course of cancer treatment to patients regardless of their social status and geographical location. Social policies aimed at improving the broader social and physical environments (e.g., poverty reduction, better community access to walking paths, parks, green spaces, or places for physical activity, and improved access to healthy, affordable food) are needed to reduce inequalities in cancer-related health behaviors, which, in turn, should lead to reduced inequalities in cancer mortality. Moreover, improving access to cancer-related healthcare and cancer screening programs among the disadvantaged has the potential to substantially reduce the cancer burden and cancer disparities among population groups and geographic areas [5].

2.5. Conclusions. Socioeconomic deprivation and rural-urban continuum were both independently related to disparities in colorectal, prostate, breast, and cervical cancer mortality among US whites and blacks. Higher mortality rates were generally found in more deprived groups and rural areas, with inequalities being particularly marked in cervical, prostate, and colorectal cancer mortality. The impact of deprivation on cancer mortality was considerably greater than

that of rural-urban continuum. Blacks experienced higher mortality from each cancer than whites across deprivation and urbanization levels. Socioeconomic gradients in cancer mortality were steeper in nonmetropolitan than in metropolitan areas. Inequalities in site-specific cancer mortality may be related to disparities in diet, obesity, physical activity, smoking, alcohol use, cancer screening, and treatment.

Conflicts of Interest

The authors declare that there is no conflict of interests.

Disclosure

The views expressed are the authors' and not necessarily those of the Health Resources and Services Administration or the US Department of Health and Human Services. No IRB approval was required for this study, which is based on the secondary analysis of public-use federal databases.

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