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The geographic variation in the cost of the opioid crisis

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The Geographic Variation in the Cost of the Opioid Crisis

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AEI Economics Working Paper 2018-03

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The Geographic Variation in the Cost of the Opioid Crisis

Alex Brill and Scott Ganz¹

March 20, 2018

Abstract

As the opioid epidemic worsens in the United States, the toll it imposes on the US economy has risen to staggering heights. The White House Council of Economic Advisers recently estimated the economic burden, inclusive of the value of statistical lives lost, to be \$504 billion in 2015. More narrowly constructed estimates find cost burdens as high as \$95 billion in 2016.

We estimate per-capita state-level and county-level non-mortality and total economic burdens of the opioid crisis in 2015 by distributing national estimates based on variation in local wages, health care costs, and criminal justice costs along with variation in opioid-related death and addiction rates, and average age-adjusted value of statistical lives lost. Our findings indicate that among the lower 48 states in 2015, per-capita non-mortality costs were highest in the District of Columbia (\$493) and New Hampshire (\$360). Median per-capita non-mortality costs were \$205 in Kentucky and Pennsylvania. Per-capita total costs (including mortality costs) were highest in West Virginia (\$4,378) and the District of Columbia (\$3,657). Median per-capita total costs were \$1,672 in Nevada.

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I. Introduction

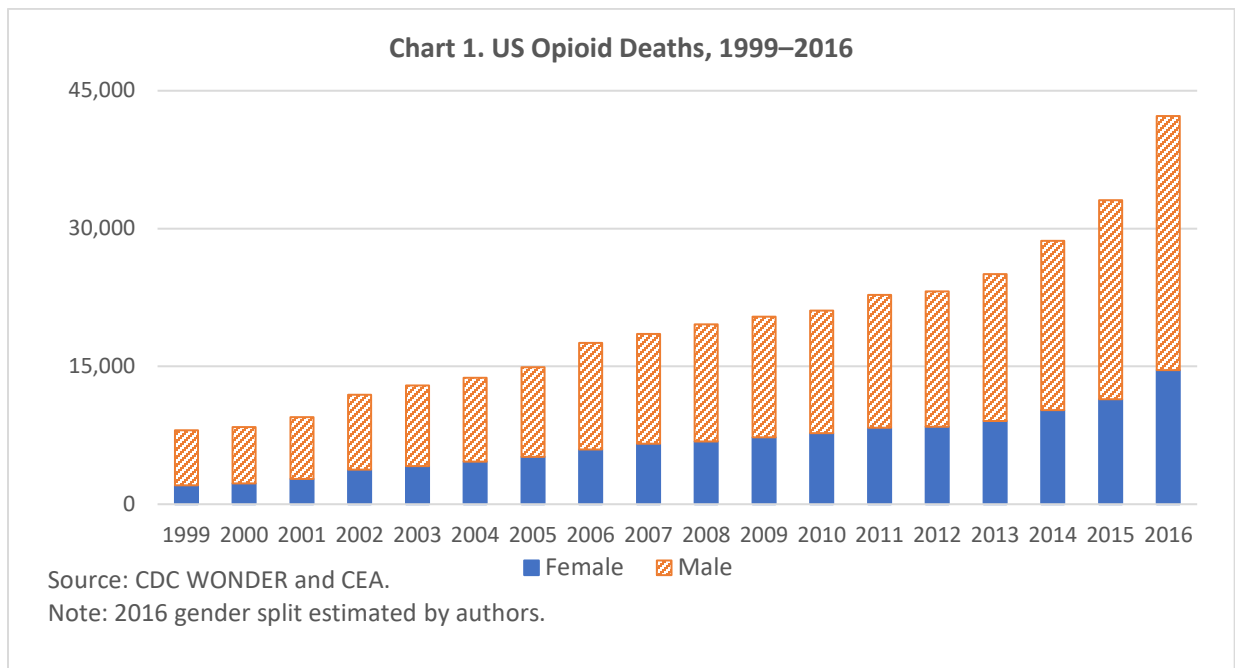
Opioid abuse is an epidemic in the United States, claiming more than 42,000 lives in 2016 alone (CDC 2017c). In addition to its devastating impact on families and communities, the opioid epidemic is costing the US economy tens of billions, if not hundreds of billions, of dollars annually. The types of costs attributable to opioid abuse – health care costs, criminal justice costs, and lost productivity, for example – are fairly well understood, as is the economic impact of the crisis at the national level. However, the economic burden of the opioid epidemic is unevenly distributed across the country, with many communities especially hard hit. As federal, state, and local policymakers and stakeholders seek to curb the epidemic, it is vitally important that they know how these costs are distributed.

In this paper, we estimate the spatial distribution of the economic burden of the opioid crisis in the United States. After discussing the scope of the problem and reviewing the existing literature on the costs of the opioid crisis, we present results from an original model that distributes these costs at the state and county levels.

II. Background

The Scope of the Opioid Epidemic

Opioids are claiming an alarming and increasing number of lives in the United States, and the epidemic has worsened drastically in recent years. The number of deaths in the United States attributable to opioids increased more than fivefold from 8,048 in 1999 to 42,249 in 2016, as illustrated in Chart 1. The National Institute on Drug Abuse (NIDA) now estimates that 115 Americans die daily from prescription opioid analgesics, heroin, and fentanyl (2018).



According to NIDA, roughly 21–29 percent of patients prescribed opioids for chronic pain misuse them (2018). Among people who misuse prescription opioids, 8–12 percent develop an opioid use disorder, and an estimated 4–6 percent who misuse prescription opioids transition to heroin (NIDA 2018). Opioid

abuse imposes great hardship and pain on those suffering from addiction, their families, and their communities. The Centers for Disease Control (CDC) reports that there are more than 1,000 emergency room visits every day for patients being treated for the misuse of prescription opioids (CDC 2017a) and that emergency room overdose visits jumped 30 percent from July 2016 to September 2017 in a sample of 52 jurisdictions across 45 states (CDC 2018). On top of this is the impact on productivity, family and social interactions, and quality of life.

Some measures point to a slight slowing of the supply of prescription opioids after a period of growth. The number of prescriptions per capita increased from 2006 to 2012 but then declined through 2016 to 66.5 prescriptions per 100 persons (CDC 2017b). However, the CDC also reports that “the rapid increase in heroin deaths that began in 2011 continued through 2015.” Moreover, an increasing share of individuals who suffer from opioid addiction are initiating use with heroin. That share increased from 8.7 percent in 2005 to 33.3 percent in 2015 (Cicero et al. 2017).

Policymaker Interest in Addressing the Crisis

The opioid epidemic is beginning to get the national attention it deserves, as federal, state, and local governments and nongovernmental organizations seek solutions. For example, President Trump’s Commission on Drug Addiction and the Opioid Crisis issued its final report in November 2017 with an extensive list of policy recommendations, including additional federal funding, changes to prescribing guidelines and provider education, enhanced enforcement and increased efforts aimed at drug takebacks, improved treatment and recovery efforts, and additional resources for research and development.

Members of Congress have been investigating the causes and consequences of the opioid epidemic and exploring potential policy reforms. Earlier this year, Congress agreed to provide \$6 billion over the next two years in federal funds targeted at addressing the epidemic. These funds are in addition to an opioid-related grant program to states that was established as part of the 21st Century Cures Act at the end of 2016.

At the local level, taskforces have been established from New Hampshire to Miami-Dade County to Alaska to understand the local impact and identify strategies for tackling the epidemic. Outside of government, the American Medical Association, various medical specialty groups, and researchers at universities around the country are working to evaluate and develop policy interventions, treatment options, and medical alternatives.

III. The Economic Consequences of the Opioid Crisis

While policymakers look for ways to stem the opioid epidemic, economists have been offering valuable insights on the impact of the crisis on the macroeconomy. For example, Princeton economist Alan Krueger (2017) examines the relationship between opioid prescription rates per county and the decline in labor force participation, estimating that the opioid epidemic could be responsible for 20 percent of the decline in men’s labor force participation. Goldman Sachs economists similarly concluded that the opioid epidemic is likely contributing to the decline in prime-age labor market participation (Mericle 2017). Alex Hollingsworth and Kosali Simon from the University of Indiana and Christopher Ruhm from the University of Virginia find that higher unemployment rates at the county level are associated with higher opioid death rates and increased emergency room visits (Hollingsworth, Ruhm, and Simon 2017).

The Federal Reserve is also examining opioid addiction's potential impact on the availability of labor in some markets and its burden on society. These questions have been the subject of testimony by former Fed Board Chair Janet Yellen² and the topic of discussion and investigation at the Cleveland, Boston, Richmond, and Minneapolis Federal Reserve Banks.

Estimates of the Aggregate Cost of the Opioid Crisis

Many experts have estimated the direct and indirect costs that the opioid epidemic imposes on our society. Some researchers have focused on a segment of the population or a particular type of expenditure induced by opioid abuse while others have taken a more comprehensive approach.

In 1998–2002, as widespread problems with opioid addiction were taking hold in the United States, the average difference in health care spending on a patient who abused opioids and a patient who did not abuse opioids was estimated to be \$14,054 (White et al. 2005). In 2002–2003, Medicaid beneficiaries with opioid abuse or dependence were estimated to have costs \$5,874 higher than those without opioid abuse or dependence; controlling for baseline characteristics increased this difference to \$15,120 (McAdam-Marx et al. 2010). In 2003–2007, excess costs among those who abuse opioids compared to those who do not averaged \$15,183 in Medicaid and \$20,546 in private insurance (White et al. 2011). A more recent study arrived at a slightly lower estimate in the commercially insured population, finding that average annual health care spending on a person who abused opioids in 2012–2015 was \$14,810 more than spending on someone who did not abuse opioids (Kirson et al. 2017).

The cost of opioid abuse is not confined to health care. Several studies have provided more comprehensive estimates that also include the workplace and criminal justice burdens attributable to the opioid crisis. All three categories of costs were estimated by health economists Howard Birnbaum and Alan White to total \$8.6 billion in 2001 (Birnbaum et al. 2006). Since then, costs have continued to climb. An early 2011 analysis yielded an estimate of \$53.4 billion in health care, workplace, and criminal justice costs associated with opioid abuse in 2006 (Hansen et al. 2011). Later in 2011, Birnbaum and White returned to the subject of their 2006 study and estimated that opioid costs in 2007 were \$55.7 billion (Birnbaum et al. 2011). Elaborating on the increase in costs between 2001 and 2007, Birnbaum and coauthors explained:

Although differences in data and methods preclude exact comparison with previous societal estimates, it is clear that the costs of opioid abuse have increased substantially due to changes in the prevalence of opioid abuse and associated costs. Key changes include, for example, increases from 2001 to 2007 . . . in the prevalence of opioid abuse (approximately 13%), the excess cost per opioid abuse patient (47% after adjusting for inflation), the cost of substance abuse treatment (up to 48%), the proportion of substance abuse admissions attributable to opioids (138%), and total police and legal expenditures (16% and 10%, respectively). (Birnbaum et al. 2011, 662–663.)

In 2016, CDC researchers incorporated the cost of lost productivity from premature deaths due to opioid overdoses, estimating the total economic impact of the opioid epidemic to be \$78.5 billion in 2013

² See, e.g., Jeanna Smialek, "Yellen Says Opioid Use Is Tied to Declining Labor Participation," Bloomberg, July 13, 2017, available at www.bloomberg.com/news/articles/2017-07-13/yellen-says-opioid-use-is-tied-to-declining-labor-participation.

(Florence et al. 2016). An analysis released the following year by the Altarum Institute, a health policy nonprofit, also included lost productivity from overdose deaths and estimated the national economic burden in 2016 to be \$95.3 billion (Rhyan 2017).

Most recently, the White House Council of Economic Advisers (CEA) constructed an estimate that significantly exceeds all previous estimates. The difference is primarily due to CEA's incorporation of an estimate of the cost to society of the lives lost to opioids. To quantify the loss of life, CEA used a metric known as the value of statistical life (VSL), which goes beyond lost productivity. There is a range of acceptable values, including ones used by federal agencies. CEA therefore presented its results in a range with the preferred estimate based on a VSL that varies with the age of the deceased.

To arrive at a total estimated cost, CEA updated the non-mortality component (that is, health care and substance abuse treatment costs, criminal justice costs, and lost productivity) of Florence et al. (2016) and then added a new measure of the cost of fatalities. CEA's preferred estimate totals \$504 billion in 2015, which comprises \$431.7 billion in mortality costs and \$72.3 billion in health, productivity and criminal justice costs.

IV. State- and County-Level Analyses

National estimates of the economic impact of the opioid epidemic offer valuable data to policymakers seeking to grasp the magnitude of the economic burden. However, the impact of the epidemic across the United States is disparate. For example, in 2016, the number of prescription opioid deaths per 100,000 was 37.7 in West Virginia, 19.0 in Connecticut, 9.9 in Nevada, and 4.6 in Iowa (Kaiser Family Foundation 2016). Moreover, factors underlying estimates of the costs of health care, criminal justice services, and worker productivity also vary by locality. Our analysis seeks to address this gap in the literature by estimating the spatial distribution of CEA's estimate of the economic burden of the opioid crisis in the United States. Below, we first report state-level per-capita cost estimates from our analysis followed by county-level per-capita estimates. We offer estimates of both total and non-mortality costs.

Per-Capita State-Level Costs of the Opioid Crisis

To distribute the CEA estimate of the cost of the opioid crisis across the lower 48 states and the District of Columbia, we consider the geographic variation in four relevant factors: opioid-related mortality, health care costs, criminal justice costs, and worker productivity. We develop a series of models that use key state and local indicators of opioid use and opioid-related costs in order to allocate the national costs estimates to each state. The technical appendix to this paper describes the data sources and methodology by which these data were combined to construct our estimates in greater detail.

Table 1 offers a breakdown of our estimates of per-capita costs. Our results indicate that the non-mortality per-capita economic burden of the opioid crisis is highest in the District of Columbia (\$493 per resident) and lowest in Iowa (\$118 per resident). Adding mortality costs gives West Virginia by far the highest per-capita burden (\$4,378 per resident) and Nebraska the lowest (\$394 per resident).³

³ These estimates vary slightly from those reported in Brill (2018) due to an update in the data and methodology.

Table 1. Non-Mortality and Total Per-Capita Costs of the Opioid Crisis, 2015					
Rank	State	Non-mortality cost per capita	State	Total cost per capita	
1	District of Columbia	\$ 493	West Virginia	\$ 4,378	
2	New Hampshire	\$ 360	District of Columbia	\$ 3,657	
3	Connecticut	\$ 358	New Hampshire	\$ 3,640	
4	Washington	\$ 331	Ohio	\$ 3,385	
5	New York	\$ 320	Maryland	\$ 3,337	
6	Delaware	\$ 320	Massachusetts	\$ 3,151	
7	Maryland	\$ 317	Rhode Island	\$ 2,820	
8	Oregon	\$ 298	Connecticut	\$ 2,736	
9	Ohio	\$ 289	Delaware	\$ 2,530	
10	Rhode Island	\$ 282	Maine	\$ 2,456	
11	Massachusetts	\$ 281	Kentucky	\$ 2,412	
12	Virginia	\$ 279	Tennessee	\$ 2,066	
13	Colorado	\$ 278	Michigan	\$ 2,012	
14	California	\$ 275	New Mexico	\$ 1,967	
15	New Jersey	\$ 267	Pennsylvania	\$ 1,945	
16	Arizona	\$ 242	Vermont	\$ 1,919	
17	Nevada	\$ 237	New Jersey	\$ 1,907	
18	West Virginia	\$ 228	New York	\$ 1,850	
19	New Mexico	\$ 226	Utah	\$ 1,827	
20	Minnesota	\$ 217	Missouri	\$ 1,727	
21	Vermont	\$ 216	North Carolina	\$ 1,711	
22	Tennessee	\$ 211	Wisconsin	\$ 1,699	
23	Missouri	\$ 207	Illinois	\$ 1,691	
24	Georgia	\$ 206	Florida	\$ 1,676	
25	Kentucky	\$ 205	Nevada	\$ 1,672	
26	Pennsylvania	\$ 205	Virginia	\$ 1,624	
27	Michigan	\$ 201	South Carolina	\$ 1,501	
28	Wisconsin	\$ 196	Washington	\$ 1,497	
29	Maine	\$ 195	Arizona	\$ 1,385	
30	Indiana	\$ 188	Colorado	\$ 1,373	
31	Illinois	\$ 186	Indiana	\$ 1,365	
32	North Carolina	\$ 180	Oklahoma	\$ 1,330	
33	Florida	\$ 176	Oregon	\$ 1,260	
34	Wyoming	\$ 176	Georgia	\$ 1,114	
35	Alabama	\$ 171	Minnesota	\$ 1,048	
36	Utah	\$ 169	North Dakota	\$ 995	
37	Idaho	\$ 165	Idaho	\$ 930	
38	Oklahoma	\$ 161	Wyoming	\$ 908	
39	Kansas	\$ 160	Louisiana	\$ 907	
40	Louisiana	\$ 153	Arkansas	\$ 897	

41	North Dakota	\$	152	Alabama	\$	892
42	Montana	\$	151	California	\$	847
43	South Dakota	\$	145	Kansas	\$	745
44	South Carolina	\$	145	South Dakota	\$	736
45	Texas	\$	144	Iowa	\$	705
46	Arkansas	\$	143	Mississippi	\$	703
47	Mississippi	\$	138	Texas	\$	653
48	Nebraska	\$	126	Montana	\$	596
49	Iowa	\$	118	Nebraska	\$	394

Note: See technical appendix for data and methodology.

Charts 2 and 3 show each state's per-capita costs, ranked by quintile. Chart 2 illustrates the per-capita health care, criminal justice, and productivity costs. Chart 3 includes the additional costs associated with the loss of life.

Chart 2. Non-Mortality Opioid Costs Per Capita by State in 2015

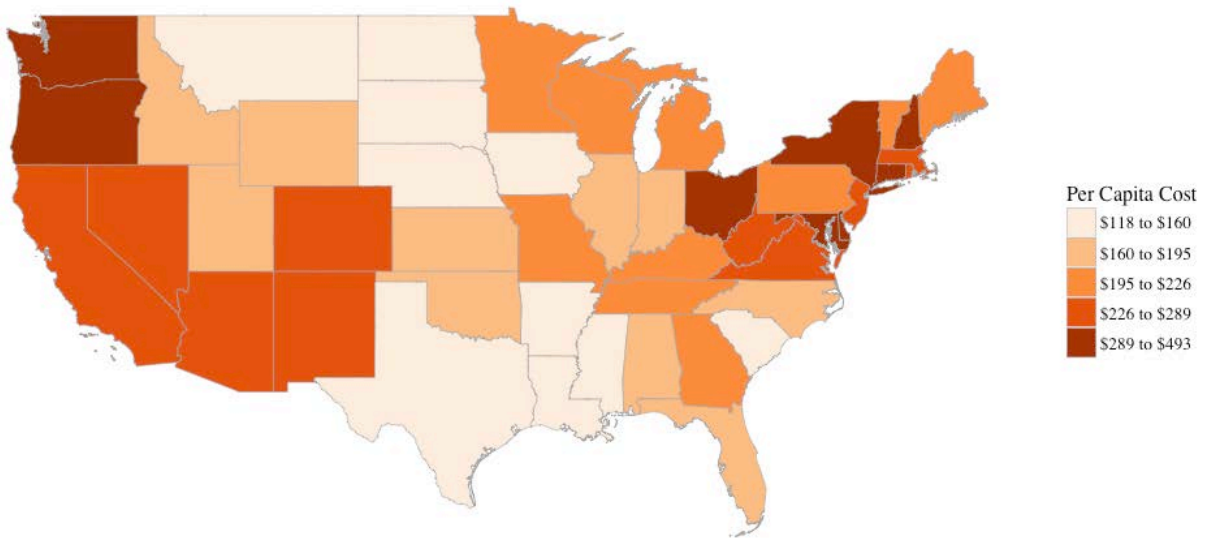
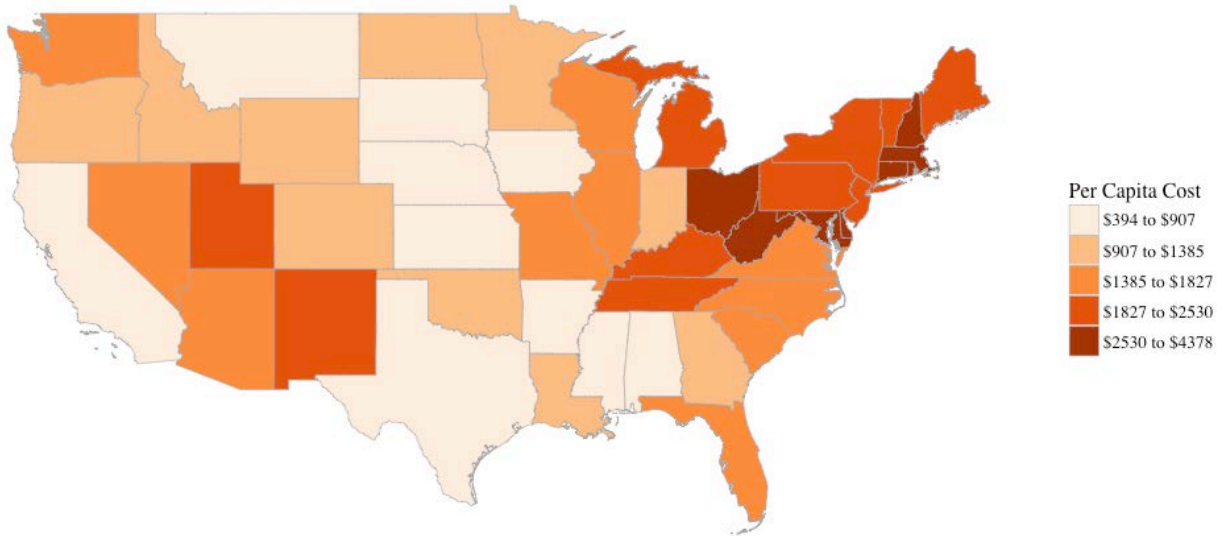


Chart 3. Total Opioid Costs Per Capita by State in 2015



Per-Capita County-Level Costs of the Opioid Crisis

While state-level estimates are more informative than national estimates, there is also wide variation within states in opioid abuse and death rates. For this reason, county-level estimates of the cost of the epidemic can offer valuable insights as well. The county-level analysis reallocates the state-level costs among the counties within each state.

As in the state analysis, the counties with the highest non-mortality costs per capita are not necessarily the same as those with the highest total costs. Table 2 lists the top 30 counties with populations of over 2,500 ranked by non-mortality and total costs. The highest non-mortality per-capita costs are primarily in counties in California, Colorado, and Virginia, while highest total costs are in counties in Kentucky and West Virginia. The non-mortality results are driven by a combination of abuse rates and health care costs, and the total costs are driven primarily by estimated deaths per capita.

Rank	County	State	Non-Mortality Cost	County	State	Total Cost
1	Jackson	IN	\$ 727	Boone	WV	\$ 8,734
2	Tuolumne	CA	\$ 723	Harrison	KY	\$ 8,546
3	Owsley	KY	\$ 629	Cabell	WV	\$ 8,339
4	Glenn	CA	\$ 608	Baltimore	MD	\$ 7,984
5	Lake	CA	\$ 599	Wayne	WV	\$ 7,718
6	San Francisco	CA	\$ 567	Rio Arriba	NM	\$ 7,294
7	Calaveras	CA	\$ 555	Mingo	WV	\$ 6,916
8	Butte	CA	\$ 554	Summers	WV	\$ 6,845
9	Harlan	KY	\$ 515	Berkeley	WV	\$ 6,722
10	Baltimore	MD	\$ 502	Washington	ME	\$ 6,523
11	District of Columbia	DC	\$ 493	Carbon	UT	\$ 6,365
12	Dickenson	VA	\$ 485	Hampshire	WV	\$ 6,359
13	Sioux	ND	\$ 477	Powell	KY	\$ 6,143
14	Mendocino	CA	\$ 463	Dickenson	VA	\$ 6,127
15	Mille Lacs	MN	\$ 461	Wyoming	WV	\$ 5,944
16	Humboldt	CA	\$ 452	Allegany	MD	\$ 5,882
17	Plumas	CA	\$ 451	Pocahontas	WV	\$ 5,843
18	Richmond	NY	\$ 449	Mercer	WV	\$ 5,807
19	Buchanan	VA	\$ 449	McDowell	WV	\$ 5,726
20	Wise	VA	\$ 440	Webster	WV	\$ 5,694
21	Tehama	CA	\$ 440	Montgomery	OH	\$ 5,626
22	Suffolk	NY	\$ 436	Lincoln	WV	\$ 5,541
23	Russell	VA	\$ 435	Ross	OH	\$ 5,433
24	Rio Arriba	NM	\$ 431	Scott	IN	\$ 5,429
25	Baltimore	MD	\$ 428	Martin	KY	\$ 5,374
26	Shasta	CA	\$ 427	Leslie	KY	\$ 5,345
27	Hillsborough	NH	\$ 425	Bell	KY	\$ 5,332
28	Tazewell	VA	\$ 425	Butler	OH	\$ 5,315
29	Multnomah	OR	\$ 421	Clinton	KY	\$ 5,292
30	New York	NY	\$ 421	Mason	WV	\$ 5,257

Note: See technical appendix for data and methodology.

Charts 4 and 5 show the per-capita costs borne by each county ranked by quintile. Chart 4 illustrates the per-capita health care, criminal justice, and productivity costs. Chart 5 includes the additional costs associated with the loss of life.

Chart 4. Non-Mortality Opioid Costs Per Capita by County in 2015

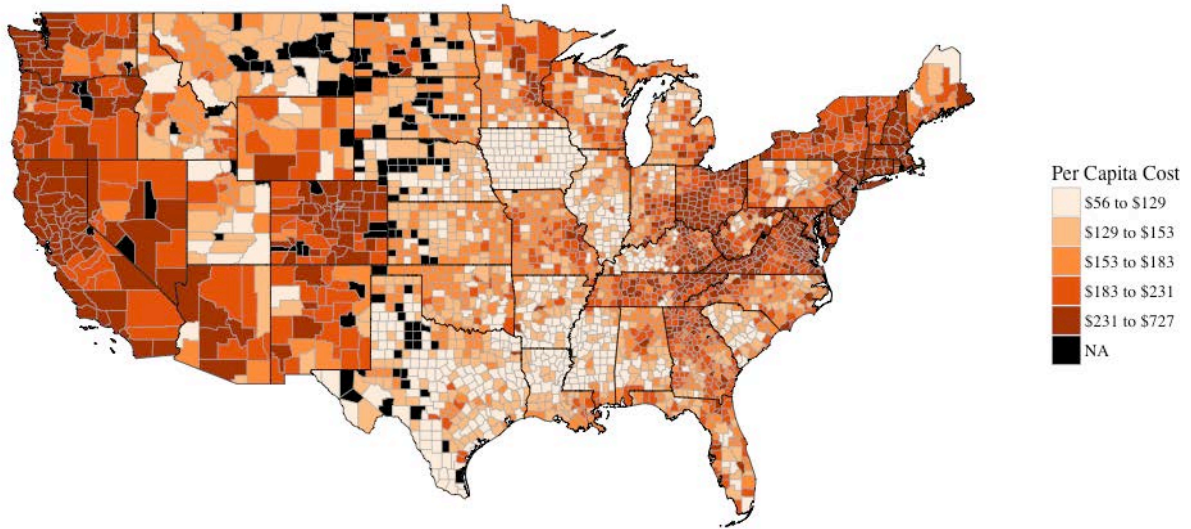
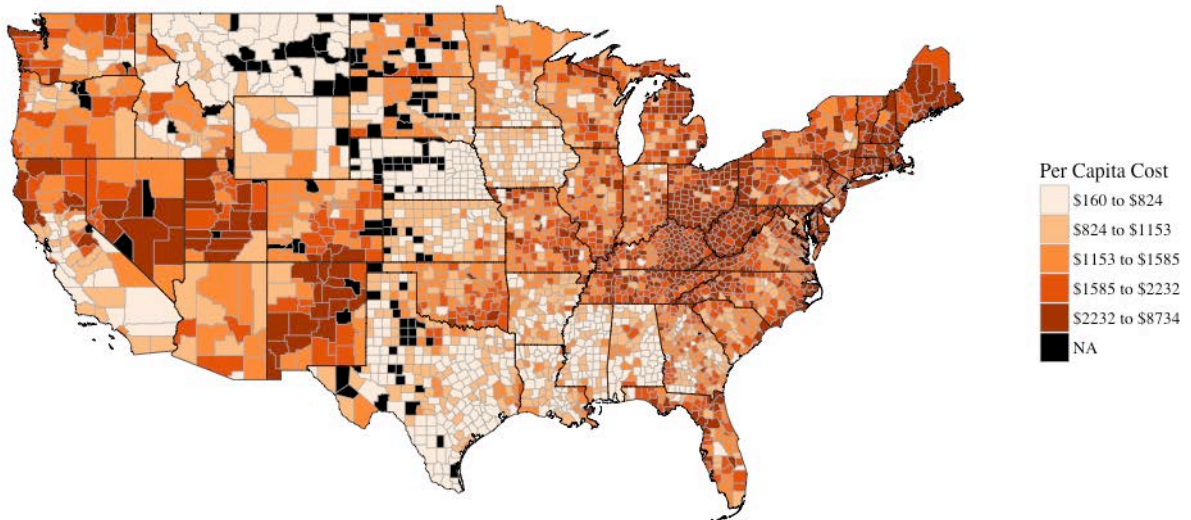


Chart 5. Total Opioid Costs Per Capita by County in 2015



V. Conclusion

The misuse and abuse of prescription opioids as well as the addiction and abuse of heroin in the United States imposes incredible hardship on those who are addicted, their families, communities, and the economy more broadly. As overdose deaths and costs associated with opioid abuse rise, policymakers are increasingly looking for ways to stem the epidemic. Identifying the local per capita economic burdens should inform policymakers in this effort.

Technical Appendix: Methodology and Data

Our model seeks to allocate the Council of Economic Advisers (CEA 2017) national cost estimates in each cost category (mortality, health care, criminal justice, and productivity) to each state in the state-level analysis. Then, we distribute the state costs in each cost category among the counties in the county-level analysis. We restrict our county-level analysis to counties with populations over 2,500.

Mortality Costs

We determine the weights to distribute the mortality costs using estimates of opioid-related deaths derived from the Centers for Disease Control (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) database.

We capture deaths associated with the following ICD-10 codes for 2016: F11.0 (Mental and behavioural disorders due to use of opioids, acute intoxication), F11.1 (Mental and behavioural disorders due to use of opioids, harmful use), F11.2 (Mental and behavioural disorders due to use of opioids, dependence syndrome), F11.3 (Mental and behavioural disorders due to use of opioids, withdrawal state), F11.4 (Mental and behavioural disorders due to use of opioids, withdrawal state with delirium), F11.5 (Mental and behavioural disorders due to use of opioids, psychotic disorder), F11.6 (Mental and behavioural disorders due to use of opioids, amnesic syndrome), F11.7 (Mental and behavioural disorders due to use of opioids, residual and late-onset psychotic disorder), F11.8 (Mental and behavioural disorders due to use of opioids, other mental and behavioural disorders), F11.9 (Mental and behavioural disorders due to use of opioids, unspecified mental and behavioural disorder), T40.0 (Opium), T40.1 (Heroin), T40.2 (Other opioids), T40.3 (Methadone), T40.4 (Other synthetic narcotics), T50.7 (Analeptics and opioid receptor antagonists), and Y45.0 (Opioids and related analgesics).

For state, s , mortality-related costs, m_s , are calculated using the following methodology. CEA (2017) estimates that overall mortality-related costs in 2015 were \$431.7 billion. Let d_s indicate the number of opioid-related deaths in state, s .

$$w_s = \frac{d_s}{\sum_s d_s}$$

$$m_s = w_s \times \text{Overall Mortality Costs}$$

We use the same methodology to allocate mortality-related costs among counties within states. However, CDC WONDER only reports opioid-related deaths for 728 out of approximately 3,000 US counties. Therefore, we model the number of opioid-related deaths where the data are missing using one of two models. For 1,885 of the remaining counties, we have data on overall drug-related deaths (ICD-10: Drug poisonings (overdose) Unintentional (X40-X44), Drug poisonings (overdose) Suicide (X60-X64), Drug poisonings (overdose) Homicide (X85), Drug poisonings (overdose) Undetermined (Y10-Y14)). In these counties, we predict the number of opioid-related deaths using a mixed-effects negative binomial model. In the model, we use the following dependent variables: the log of the count of drug-related deaths, the log of the estimated number of people who use pain relievers for nonmedical use, the log of the population, the log of the median household income in the county, the proportion of the population who live in rural areas, the proportion of the population who are Black, the proportion of the population who are Hispanic, and the proportion of the population who have not graduated high school.

The model also includes a state-level random effect. For the remaining 526 counties, we use the same model, excluding the count of drug-related deaths as a covariate.

We allocate mortality-related costs among the counties within a state using the following methodology. Let $d_{s,c}$ indicate the estimated number of deaths in county, c , in state, s , and $m_{s,c}$ represent the predicted mortality-related costs within each county.

$$w_{s,c} = \frac{d_{s,c}}{\sum_{c \in s} d_{s,c}}$$

$$m_{s,c} = w_{s,c} \times m_s$$

Health Care Costs

We determine the weights associated with health care costs using opioid-related hospitalization cost estimates from the Agency for Healthcare Research and Quality’s Healthcare Cost and Utilization Project (HCUP). HCUP reports the total number of discharges and total costs associated with opioid-related conditions for 32 states (Arkansas, Arizona, California, Florida, Hawaii, Iowa, Illinois, Indiana, Kentucky, Louisiana, Massachusetts, Maryland, Maine, Michigan, Minnesota, North Carolina, North Dakota, New Jersey, New Mexico, Nevada, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Washington, Wisconsin, West Virginia, and Wyoming).

We estimate hospitalization costs in the remaining states and D.C. with a linear regression model. We predict the log of opioid-related hospitalization costs using the log of total population, the log of statewide opioid deaths, Medicare’s Physician Fee Schedule associated with critical care (CPT code 99291), and log median per-capita income. We then exponentiate this prediction and correct for potential non-normality of the residuals to arrive at a state-level hospitalization cost estimate.

For state, s , health care costs, h_s , are estimated as follows. CEA (2017) estimates that overall health care costs in 2015 were \$36.6 billion. Let h'_s indicate either the HCUP estimate of state-level opioid-related hospitalization costs or the prediction derived from our model.

$$x_s = \frac{h'_s}{\sum_s h'_s}$$

$$h_s = x_s \times \text{Overall Healthcare Costs}$$

For the county-level estimates, we allocate the state-level costs among the counties within each state. However, HCUP only reports county-level opioid-related hospitalization costs for 1,330 counties. For the remaining counties, we estimate hospitalization costs in the following manner. For counties for which we have estimates of opioid-related deaths ($n = 251$), we estimate a mixed-effects linear regression in which we predict the log of total hospitalization costs using the log of opioid deaths, local Physician Fee Schedule for critical care, log of population, log of overall drug deaths, and log of the number of people who use pain relievers for nonmedical use, along with a state-level random effect. We use this model to predict the total hospitalization costs for each county. For counties for which we have data on overall drug-related deaths, we estimate the same model, excluding opioid-related deaths ($n = 1,043$). For the remainder, we estimate the same model excluding both opioid and drug-related deaths as covariates ($n = 516$).

We allocate health care costs among the counties within a state using the following methodology. Let $h'_{s,c}$ indicate the estimated opioid-related hospitalization costs in county, c , in state, s , and $h_{s,c}$ represent the predicted health care costs within each county.

$$x_{s,c} = \frac{h'_{s,c}}{\sum_{c \in S} h'_{s,c}}$$

$$h_{s,c} = x_{s,c} \times h_s$$

Productivity Costs

We determine the weights associated with opioid-related productivity loss using household median income, state-level working age population, the proportion of people in the state who use pain relievers for nonmedical use, and the overall loss of productivity due to opioid abuse or dependence. The proportion of individuals who use pain relievers for nonmedical use is collected from the Substance Abuse and Mental Health Services Administration National Surveys on Drug Use and Health from 2012 to 2014. In addition, Florence et al. (2016) estimates that drug abuse/dependence contributes to a 17–18 percent decrease in productivity.

We first estimate county-level productivity costs, and then aggregate to the state level. For county, c , in state, s , productivity costs, $p_{s,c}$, are estimated as follows. Let $i_{s,c}$ represent median household income in the state, let $n_{s,c}$ represent the population between 25 and 64 years of age, and let $u_{s,c}$ represent the proportion of people who use pain relievers for nonmedical use. CEA (2017) estimates that overall productivity costs in 2015 were \$25.9 billion.

$$y_{s,c} = \frac{i_{s,c} \times n_{s,c} \times u_{s,c} \times 0.175}{\sum_{s,c} i_{s,c} \times n_{s,c} \times u_{s,c} \times 0.175}$$

$$p_{s,c} = y_{s,c} \times \text{Overall Productivity Costs}$$

We then aggregate county-level costs to the state-level in order to derive state-level estimates of productivity costs, p_s .

$$p_s = \sum_{c \in S} p_{s,c}$$

Criminal Justice Costs

We lack local estimates of criminal justice costs, unlike prior categories. Instead, we utilize state-level estimates of per-capita criminal justice costs and weight them among counties proportionally according to the number of individuals who use pain relievers for nonmedical use.

For county, c , in state, s , criminal justice costs, $c_{s,c}$, are estimated as follows. CEA (2017) estimates that overall criminal justice costs in 2015 were \$9.7 billion. Let c'_s represent per-capita criminal justice expenditures, as reported by the Bureau of Justice Statistics (2015); let $n_{s,c}$ represent the overall county population; and let $u_{s,c}$ represent the proportion of people who use pain relievers for nonmedical use.

$$z_{s,c} = \frac{c'_s \times n_{s,c} \times u_{s,c}}{\sum_{s,c} c'_s \times n_{s,c} \times u_{s,c}}$$

$$c_{s,c} = z_{s,c} \times \text{Overall Criminal Justice Costs}$$

We then aggregate county-level costs to the state-level in order to derive state-level estimates of criminal justice costs, c_s .

$$c_s = \sum_{c \in S} c_{s,c}$$

Overall Cost Estimates

Non-mortality costs are the sum of health care costs, productivity costs, and criminal justice costs. Specifically, for states and counties, non-mortality costs equal $h_s + p_s + c_s$ and $h_{s,c} + p_{s,c} + c_{s,c}$, respectively. Total costs also include mortality costs. Specifically, for states and counties, total costs equal $m_s + h_s + p_s + c_s$ and $m_{s,c} + h_{s,c} + p_{s,c} + c_{s,c}$, respectively.

In the paper, we present per-capita estimates. These equal cost estimates divided by population.

Replication files are available upon request from the authors.

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