ESTIMATING THE COSTS OF THE OPIOID EPIDEMIC

METHODS

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ANALYTICAL APPROACH FOR ESTIMATING THE COSTS OF THE OPIOID EPIDEMIC

The VCU Center on Society and Health collaborated with Altarum to estimate productivity, health care costs, and government losses from the opioid epidemic in the Commonwealth of Virginia builds on prior work that has measured the total burden of the opioid crisis in the United States and Ohio. The approach leverages datasets and tools previously developed to measure the costs and benefits of health and health-related interventions, including strategies developed for the Altarum Value of Health analytical model. The estimation of Virginia's county-specific losses combines the best available local data on the opioid crisis – including health care utilization data provided by the Department of Health – with data on county characteristics, while incorporating academic and grey literature on the impacts of opioid use and misuse in the United States. The work estimates economic costs incurred by opioid use during the years 2018, 2019, and 2020, the most recent year for which key data inputs were available at the time of analysis.

The modeling process involves first calculating or estimating specific components of the opioid epidemic for the entire Commonwealth and for each county and independent city (such as the number of overdose fatalities and number of individuals suffering from an opioid use disorder). The economic costs of the productivity losses resulting from each of these opioid crisis impacts are computed using effect sizes from the academic and grey literature; local economic data on population, tax rates, and expected earnings; and models developed to estimate the impacts of lost productivity on households, the private sector, and federal/state governments, government expenditures required to address opioid abuse, and the health care costs of specific opioid-related health care utilization events. For some components, sensitivity analyses are then completed on some of the model inputs to help describe some of the uncertainty around the economic cost estimates. The below sections detail the data sources used for each major productivity cost component in this work and any specific modeling coefficients or assumptions applied in the calculations.

PRODUCTIVITY LOSSES DUE TO OPIOID OVERDOSE FATALITIES

Estimates of the number of overdose deaths in 2018, 2019, and 2020 rely on data from the Centers for Disease Control and Prevention (CDC) Multiple Causes of Death Data, provided by Virginia public health experts. These data were collected from the Virginia Department of Health (VDH) website, specifically information on "All Opioid" related deaths. The definition of an opioid overdose death is designed to match as closely as possible the categorization from the National Vital Statistics System data on Drug Overdose Death Counts, and includes drug categories of heroin, prescription opioids, synthetic drugs like fentanyl, and other unspecified narcotics:

> *Drug overdose deaths are identified using underlying cause-of-death codes from the Tenth Revision of ICD (ICD–10): X40–X44 (unintentional), X60–X64 (suicide), X85 (homicide), and Y10–Y14 (undetermined). Drug overdose deaths involving selected drug categories are identified by specific multiple cause-of-death codes. Drug categories presented include: heroin (T40.1); natural opioid analgesics, including morphine and codeine, and semisynthetic opioids, including drugs such as oxycodone, hydrocodone, hydromorphone, and oxymorphone (T40.2); methadone, a synthetic opioid (T40.3); synthetic opioid analgesics other than methadone, including drugs such*

as fentanyl and tramadol (T40.4); cocaine (T40.5); and psychostimulants with abuse potential, which includes methamphetamine (T43.6).

Opioid overdose deaths are identified by the presence of any of the following MCOD codes: opium (T40.0); heroin (T40.1); natural opioid analgesics (T40.2); methadone (T40.3); synthetic opioid analgesics other than methadone (T40.4); or other and unspecified narcotics (T40.6).

In prior analyses for Virginia, the county-level detail was often not available because death data counts and rates were suppressed for any individual statistic computed with a count of less than 10 individuals in CDC WONDER files. As a result, the Altarum approach sometimes applied data from multiple years, from neighboring counties, or from the entire state to estimate the number of fatalities. As a result of the change for the 2018 data onward, a more precise estimate of productivity losses for the state have been made. All county death counts are inflated by two percent, to adjust for missing data on death certificates and in the CDC mortality data. Virginia's adjustment is very minor compared to other states, see Ruhm (2017) Geographic Variation in Opioid and Heroin Involved Drug Poisoning Mortality Rates for an explanation and detailed data on adjustment rates by state.

The age distribution of opioid deaths in each county is also required to estimate the total lost future earnings for each fatality. We estimated the age-distribution of deaths in each county and independent city based on the single-year age distribution of opioid overdose deaths for the entire Commonwealth for the ages most commonly accounting for opioid deaths (ages 21 to 62) and then from the age distribution for the entire United States, rescaled to match the average Virginia rate, for all other ages. Supplemental population data were required for this approach and were taken from the US Census National and State Population Estimates.

In order to estimate the economic and productivity losses from each opioid overdose fatality, we apply methods used in Altarum's Value of Health modeling using data on earnings, tax rates, and non-opioid related mortality rates. Non-opioid mortality rate estimates are also taken from the CDC WONDER mortality data. Estimated effective tax rates are taken from outputs of the NBER TAXSIM model for the state of Virginia and are applied evenly to each county and individual independent city. Lost future earnings by age are estimated for each county by applying individual annual earnings by age from 2017 American Community Survey 1-year microdata, smoothed using a 5-year moving average, and adjusted to each Virginia county using data on the median county income for an individual with a high-school diploma relative to the state and national average of this statistic for 2017. The median county income was again based on American Community Survey data accessed from the American Fact Finder data portal.

To estimate the 2018, 2019, and 2020 economic impact of lost future productivity, we apply the following assumptions to the earnings data: a 1% annual real growth rate in future earnings for all individuals and a 3% annual discount rate to all earnings in future years. These assumptions are relaxed in the sensitivity analyses described in the work summary. Lost productivity costs are apportioned to households and the private sector, the federal government and state government using the tax rate data from above and Altarum Value of Health Tool methods.

PRODUCTIVITY LOSSES DUE TO NONFATAL OPIOID USE DISORDERS

Productivity losses due to nonfatal opioid misuse are calculated from the estimated count of individuals suffering from an opioid use disorder (OUD), county incomes, and the estimated impact each OUD has on productivity and earnings.

The counts of opioid use disorders are estimated using data from the National Survey on Drug Use and Health (NSDUH). We apply state-level rates of pain-reliever use disorders from the state-level surveys and tables, and adjust these data to estimate the total state rate of OUD based on the relative national proportion of OUDs to prescription pain-reliever use disorders in the national surveys. We further estimate county and independent city rates, by applying data on the relative severity of the opioid epidemic from the 2016-2018 substate NSDUH heroin use rates for five regions across the Commonwealth of Virginia (unfortunately, only heroin use rates are available in the substate data). Because the state-level and substate level NSDUH data cover multiple years, we apply the surveys to the year of the final year of the multi-year surveys, e.g. to estimate the state ratio of opioid use disorder to pain-reliever use disorder in 2019, we use the 2018-2019 state estimates.

OUD rates are then applied to the 2018, 2019, and 2020 population estimates from above to estimate the total number of individuals suffering from an OUD by county. The total productivity loss and economic impact of this opioid misuse is computed by applying data from prior research on the impact of substance use disorders on labor force participation and wages and the county level earnings data from above. These costs are then apportioned by payer using the methods of the Value of Health tool described above.

PRODUCTIVITY LOSSES DUE TO INCARCERATION

The final component of opioid productivity impacts is estimated for the population of state residents incarcerated due to drug crimes related to opioids. While small, this component estimates the impact of lost workforce participation and earnings for 2018, 2019, and 2020 from those incarcerated. Estimates of the state incarcerated population are taken from the Bureau of Justice Statistics Prisoners reports and the number of those imprisoned for drug crimes is estimated by applying the national percentage of inmates incarcerated for drug-related crimes to the total state incarcerated population. The percentage of these drug crimes related to opioids was estimated using the ratio of opioid substance use disorders to all substance use disorders from the NSDUH data. Total earnings lost are estimated using the earnings data from above. Our estimates of lost productivity due to incarceration do not include the costs of criminal justice or government contributions to prison costs but are solely the lost potential earnings of individuals who have been incarcerated.

HEALTH CARE COSTS DUE TO OVERDOSES AND HEALTH CRISES INVOLVING OPIOIDS

The total direct health care cost in each locality was estimated as the sum of costs from emergency visits for opioid overdose, emergency department treat-and-release visits for other opioid-related visits, inpatient stays for overdose, and inpatient stays for other opioid-related visits. For these four categories of events, we estimated hospital, ambulance, and Naloxone costs, and quantified and monetized health-care utilization by locality. To do this, best-available imputation methods were used to address missing data based on federal-, state-, and local-level evidence. To estimate the cost of each of the health care use cases, a brief literature scan was conducted through May 2020 to identify the most recent estimates of opioid health care costs, such as costs of an overdose hospitalization. Altarum's Health Spending Economic Indicators were used to adjust costs and payments for inflation over time where necessary.

Hospitalizations

For each Virginia locality, the number of opioid-attributable inpatient hospital stays for overdose and other opioid-related acute health complications were estimated. Costs and payments associated with these stays were estimated by locality, as well. Commonwealth data provided by the Virginia Department of Health on overdose hospitalizations were first incorporated to generate estimates and this was complemented federal data to identify non-overdose opioid stays.

Overdose. Estimates of the number of overdose hospitalizations in 2018-2020 are from data provided by the Virginia Department of Health (VDH) describing hospitalizations opioid-related discharges, summarized by county/independent city and by each of the 35 VDH districts. These claims-based records are from the Virginia All-Payer Claims Database (APCD) and provide additional information on mean length of stay and mean financial charges for each county's set of hospitalizations during. Annual statewide counts of hospitalizations are given by payer source, with Medicare, Medicaid, and self-pay ranking in the top three in each of the 3 years. For hospital costs, national estimates of opioid-poisoning inpatient stay costs were used (Inocencio, et al., 2013). For payments, each locality's annual charges were adjusted by national payment-to-charge ratios in Smith et al. (2015), which are given by payer; to better approximate Virginia's ratio, the national ratios were weighted according to the Commonwealth's payer mix.

Non-Overdose. The overall count of opioid-related inpatient stays is published at a state level by the Agency for Health Research and Quality's (AHRQ) Healthcare Costs and Utilization Project (HCUP). HCUP's encounter-based data also capture *overdose* inpatient stays, so the estimated overdose stays were subtracted from the estimated overall inpatient stays at the locality level to avoid double-counting. The HCUP Fast Stats report on Opioid-Related Hospital Use gave estimated 2018, 2019, and 2020 inpatient stays with opioids mentioned in the diagnostic codes. The number of inpatient visits per county was estimated from the HCUP state data, by using the VDH provided proportion of emergency department visits in each county from the state total (ED data discussed in the next section). For 2020, HCUP data on opioid inpatient hospitalizations have not yet been published, therefore we estimate this required data point based on the historical ratio of opioid overdose ED Visits to inpatient hospitalizations.

Hospital costs and total payments for these inpatient stays were estimated using average costs per opioid-related inpatient stay estimated in academic literature. Mallow et al. (2018) calculated an average

cost of $8,445 per opioid-related stay from Vizient all-payer claims data during 2014–2017, representing 34 hospitals in the Mid-Atlantic region; these costs were adjusted to account for national inflation of inpatient-care costs during that period, to arrive at a best estimate of the cost per stay of $8,644.62. Payments were estimated for non-overdose stays by applying the ratio of payments to charges for *overdose* stays for each locality, already calculated via the methodology described above.

Emergency Department Visits

Overdose. Tallies of overdose visits to the emergency department (ED) were provided by VDH, leaving the remainder of opioid-related visits to be counted and monetized separately for non-overdose visits. Surveilled overdose ED visits were counted from the April 8, 2020 version of VDH's public *Emergency Department Visits for Unintentional Drug Overdose Among Virginia Residents* statistics, which provided annual counts for ED visits for opioid overdoses by the patient's locality of residence. For overdose ED costs, the average cost per visit was applied from estimates by Inocencio et al. (2013), which were adjusted for national inflation in hospital outpatient care. Payments were estimated by applying a payment-to-cost ratio, already calculated for overdose inpatient stays, to the estimated ED cost.

Non-overdose T&R. National HCUP data allow insights about a second set of ED visits that did not result in an inpatient stay, called treat-and-release (T&R). While some of these overlap with ED visits for overdose, some are non-overdose, and thus important to include in the model. To estimate ED T&R visits by locality, each locality's estimated opioid inpatient stays were multiplied by the national ratio of opioid-related ED T&R visits to inpatient stays. These values were reported in the same Fast Stats tables that estimated sub-state inpatient stays. To avoid double counting ED visits for overdose, we subtracted the locality's overdose ED T&R visits. (We approximated the number of overdose ED visits that were T&R, we assumed all overdose inpatient stays began as an ED visit, and so we subtracted inpatient stays from surveilled ED visits for overdose.) The result are estimates of ED T&R visits for non-overdose by locality. To these, we applied costs from Inocencio et al. (2013) and adjusted for inflation to get total costs per locality. Payments were approximated by multiplying these ED T&R costs by the payment-to-cost ratio already calculated for overdose inpatient stays.

Ambulance and Naloxone Costs

Ambulance costs for ED visits for overdose, ED T&R visits for non-overdose, and non-overdose inpatient stays were calculated. (Overdose inpatient stays were assumed to be captured by the overdose ED visit data, whereas non-overdose cases could only be ED T&R or inpatient, but not both.) We multiplied our estimate of non-overdose inpatient stays by 71%, the share of opioid-related inpatient stays that originated as ED visits in the Mid-Atlantic region (Mallow et al., 2018). The overdose ED, non-overdose ED T&R, and non-overdose inpatient stays are assumed to provide mutually exclusive, comprehensively exhaustive groups of ED cases, any of which may have involved an ambulance call. Ambulances were assumed to be used in 75% of all ED cases, and ambulance costs were taken from Inocencio et al. (2013) national estimates, adjusted for inflation in general hospital-care prices from 2011 to the year of study. One naloxone dose was assumed used in all ambulance cases for overdose, multiplied by an estimated average $60 per dose.

Primary Payer of Direct Health Care Costs

To estimate the primary payment source for each direct opioid-related overdose or other health care utilization event, data provided by VDH on the breakdown of overdose charges by payer was used. Costs were then attributed to the private sector, federal government, and state government totals using data on the proportion of each coverage type paid for by each major insurer. Medicare costs were attributed to the federal government, private insurance costs to the private sector and Medicaid costs split between the state and federal government based on the fiscal year Federal Medical Assistance Percentage (FMAP) for 2018-2020.

INDIRECT HEALTH CARE COSTS OF CHRONIC DISEASE CAUSED BY OPIOID MISUSE AND ABUSE

Based on the prevalence of heroin use disorder and on VDH surveillance data of new cases of chronic diseases with known opioid-related health risks, the costs of illness attributable to opioid use were estimated. Neonatal abstinence syndrome, human immunodeficiency virus, hepatitis C and B viruses, and tuberculosis – diseases modeled by Jiang et al. (2017) – were considered.

Neonatal Abstinence Syndrome (NAS)

NAS is a suite of birth and development complications due to in-utero opioid exposure. NAS-afflicted babies born were identified using locality-level data published by VDH. Costs associated with birth were applied from Corr & Hollenbeak (2017), while non-birth costs associated with the first 8 years of life were taken by applying Liu et al.'s (2019) NAS-attributable spending multipliers to national health spending per capita for children ages 0-8. Birth and postpartum costs were separated out using estimates from Bui et al. (2017). Furthermore, age-specific spending data for 2016 from the Institute for Health Metrics and Evaluation Disease Expenditure project database (received by request from Joseph Dieleman, Ph.D.), and Child Trends population estimates by age for 2016 gave a denominator for per capita costs.

HIV, HCV, HBV, and Tuberculosis

Infections of HIV, HCV, HBV, and Tuberculosis all have lasting effects that require high medical costs to treat symptoms upon their onset. The contagious diseases spread via injection drug use, such as with heroin. We used the model provided by Jiang et al. (2017), which requires a headcount of heroin users as its input, to estimate the state's total future healthcare costs owing to new, heroin-attributable infections during 2018-2020. We estimate heroin users based on the Commonwealth's average rate of past-year heroin use among persons aged 12 or older in 2018-2020, averaging the values from the NSDUH State Prevalence Estimates. We then multiplied that rate by each locality's population over age 12 (gleaned from the Weldon Center's Demographic Research Group data, and assuming half of the group ages 10-14 in each locality is age 12 or up). Having estimated the population of heroin users estimated by locality, we applied the probabilities and costs gathered by Jiang et al. to model HIV, HCV, HBV, and Tuberculosis costs in that heroin-user group at the locality level.

For HIV and HCV, we used observed new cases to adjust the distribution of the total costs among localities without changing the Virginia total. This helps reflect that areas with higher prevalence of either disease will bear disproportionately high costs due to greater likelihood of contagion, locally. HIV and HCV are especially well tracked in publicly available data, including at the locality level, by the Virginia Department of Health. Locality-level data on HIV new diagnoses were received via data request from VDH, whereas HCV new diagnoses data were downloaded from the VDH website. Using the costs in Jiang et al.'s model, these new diagnoses were monetized; national estimates suggest 9.4% of new HIV cases and 60% of new HCV cases are linked to injection drug use, so these shares of the disease costs were applied to each locality to estimate the opioid-attributable cost from documented new cases. The remainders of the Virginia cost of illness from HIV and HCV, as modeled based on Jiang et al., were then distributed among localities according to the size of localities' estimated heroin user populations. Where applicable, costs of treatment were adjusted by Altarum's all-item measure of health-care price inflation to reflect 2018-2020 dollars.

CRIMINAL JUSTICE, CHILD/FAMILY ASSISTANCE, K-12 EDUCATION COSTS

We estimated direct expenditures on these other government expenditures for services needed to respond to the opioid epidemic and related costs for 2016 using methods from previous academic work applied to Bureau of Justice Statistics data and from estimates from the National Center on Addiction and Substance Abuse. Where necessary, opioid-related costs were apportioned from total substance use estimates using relative rates of opioid use from NSDUH and substate estimates were made using county and independent city population data.