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Jobs at Risk: Sea Level Rise, Coastal Flooding, and Local Economies

Yanjun (Penny) Liao, Sophie Pesek, Margaret Walls, and Celso Ferreira

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About the Authors

Yanjun (Penny) Liao is an economist and Fellow at Resources for the Future. Her current research focuses on issues of natural disaster risk management and climate adaptation. In a series of ongoing projects, she investigates how flood risk and the design of flood insurance program affect housing markets, the mortgage system, and location decisions of households with different demographics. She has also studied the impacts of disasters on local government budgets, housing markets, and demographic changes. In a secondary research agenda, Liao studies consumer behavior regarding the adoption of clean technology in the electricity and transportation sector.

Sophie Pesek is a Senior Research Analyst for the Climate Risks and Resilience program at Resources for the Future. Her current work focuses on natural disasters, the value of earth observation data, and the just transition. Before joining RFF, she worked on environmental projects in China, Tanzania, Suriname, and Ghana and for a water sensor startup. She graduated from Harvard University in 2020 with a BA in Environmental Science and Engineering and hopes to bring an engineering perspective to pressing policy questions in sustainability and global equity.

Margaret Walls is a Senior Fellow and director of the Climate Risks and Resilience Program and the Environmental Justice Initiative at Resources for the Future. Her current research focuses on issues related to climate impacts and disasters, including wildfires and flooding, resilience and adaptation to extreme events, ecosystem services, and conservation. She previously served on the board of the Association of Environmental and Resource Economists and was an associate professor in the Department of Economics at Victoria University in Wellington, New Zealand, from 1996 through 2000.

Celso Ferreira is an associate professor of civil, environmental, and infrastructure engineering at George Mason University. Ferreira specializes in investigating and developing solutions that increase society's resilience to flood related natural hazards. His work is focused on flood hazards from coastal, riverine, and urban environments and includes real time flood forecasting, monitoring storm surges, and supporting incoporation of natural systems into coastal flood defenses. His work investigating the capacity of natural areas to attenuate waves is providing scientific and technical evidence for the adoption of green infrastructure as a resilient form of coastal defense.

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Abstract

Coastal regions are economically important but also susceptible to sea level rise and flooding. This study assesses the exposure of local economies to tidal flooding in the Chesapeake Bay region using geolocated businesses and employment data. Our results show that approximately 263,500 jobs and $11.1 billion in wage income will be exposed to 100-year flooding by 2050, which is almost 50% higher compared to current conditions due to sea level rise. Several jurisdictions are exposure hotspots with a much higher number or share of jobs and wage income subject to flood risk. We also identify 44 census tracts that have both high flood exposure and high population vulnerability. Our results highlight the need for better coordination between state economic development and climate resilience policies to address the growing challenges of climate change in coastal regions.

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1. Introduction

Coastal regions in the United States and globally are major engines of economic growth. The US Bureau of Economic Analysis Marine Economy Satellite Account, which encompasses 10 general categories of economic activities, such as shipbuilding, national defense, commercial fishing, and tourism and recreation, estimates that the ocean economy accounted for 1.9 percent of US GDP, or $397 billion, in 2019 (US BEA 2021).

At the same time, coastal areas are highly susceptible to the forces of climate change. An average of 0.8–1 foot of sea level rise (SLR) is expected along US coasts by 2050, an increase from a 2020 baseline equivalent to that experienced over the last 100 years (Sweet et al. 2022). Projections for 2100 are 2–7 feet. SLR will cause minor, or "nuisance," high-tide flooding to increase from a US average of about 3 events per year in 2020 to more than 10 by 2050 (Sweet et al. 2022). In some locations, the increases are dramatically higher. Norfolk, Virginia, for example, had 13 days of minor high-tide flooding in 2021 but is expected to have 85–125 days by 2050.[1] Minor high-tide flooding is generally considered disruptive to daily life but not typically damaging to properties and infrastructure. According to Sweet et al. (2022), however, a flood regime shift is on its way in coastal areas, with moderate high-tide flooding, which is usually damaging, expected to occur as often as minor flooding today, and major (destructive) high-tide flooding occurring as often as moderate flooding today.

We assess the impact that tidal flooding has on local coastal economies under current conditions and in 2050 with SLR using the latest SLR projections from the National Oceanic and Atmospheric Administration (NOAA) (Sweet et al. 2022) and administrative data on geolocated business establishments from the National Establishment Time Series (NETS) Database. Our study makes three main contributions to the literature on climate change impacts in coastal areas. First, instead of calculating inundated areas for SLR scenarios (using, for example, the NOAA SLR Viewer),[2] we use methods described in Sweet et al. (2022) to generate flood outcomes for the 1-year and 100-year flood return periods for present-day and 2050 conditions. This provides information on exactly which businesses are expected to experience flooding in particular events, including as a result of SLR. Second, our study is the first to analyze impacts on jobs and wage income.[3] Several studies have assessed the number and value of properties at risk from SLR and coastal flooding (Hallegette et al. 2013; McAlpine and Porter 2018; Bernstein et al. 2019; Keys and Mulder 2020). But researchers are increasingly looking beyond property values to other features of

1 **https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html**.

2 **https://coast.noaa.gov/slr/#/layer/slr**.

3 A recent dataset from NOAA tabulates county establishments and jobs in SLR inundation areas (**https://coast.noaa.gov/digitalcoast/data/coastal-inundation-zones.html**). Compared to this data, our analysis captures broader flood exposure rather than inundation, features a more granular spatial scale, and examines additional outcomes on wage income and social vulnerability.

coastal communities, such as critical infrastructure (Qiang 2019), road access to places of employment, commercial activities, and essential facilities, such as schools and medical services (Hino et al. 2019; Kasmalkar et al. 2020; Logan et al. 2023; Loreti et al. 2022), water infrastructure and associated health outcomes (Allen et al. 2019; Mitchell et al. 2021), and migration (Hauer 2017). Together with these other studies, our results begin to draw a clearer picture of the economic viability of coastal communities in a future with more frequent and damaging flooding. Third, we combine our employment estimates with information on the social vulnerability of populations at a census tract level. This allows us to determine which areas have both high job and wage income exposure to flood risks and high population vulnerability to those risks. Several studies have found that low-income and socially vulnerable populations experience greater impacts from floods and are slower to recover (Montgomery and Chakraborty 2015; Bakkensen and Ma 2020; Tate et al. 2020; Wing et al. 2022). Our analysis provides information on the intersections between vulnerability, flood risks, and local economic opportunity.

Our findings suggest a need to coordinate state economic development policies with climate adaptation and resilience strategies. Many states promote economic development, particularly in communities that lag others in jobs, wages, and business growth. However, these can be the same communities that are more susceptible to flooding. Flood risks could be driving the economic problems. To the extent that economic development and resilience policies can reinforce each other, coastal communities will fare better in a future with climate change. We offer some suggestions for what these reinforcements might look like.

We focus our analysis on the Chesapeake Bay region—specifically, the coastal counties of Maryland and Virginia that are subject to SLR.[4] The Chesapeake Bay is the largest estuary in the United States and has an 11,684-mile shoreline, longer than the west coast of the continental United States. Many communities there suffer from tidal flooding, and relative sea levels are projected to increase more than the national average, in part due to land subsidence. Jobs in the coastal counties of Maryland and Virginia account for 52 percent of all jobs in the two states, so the coast is an important driver of the states' economies. The region is economically diverse, home to beachfront tourist destinations, small towns on the Bay and its tributaries, and a large military presence in Norfolk and the surrounding Tidewater region.

Our analysis reveals that approximately 176,500 jobs in the region are exposed to flooding in the 100-year event under current conditions, which will rise to about 263,500 by 2050 with SLR. These numbers represent 3.3 and 5 percent of all jobs in coastal counties and cities now and in 2050, respectively. These averages mask large geographic variability, however. Counties with large coastal urban areas are expected to have many jobs impacted by a 100-year flood: Baltimore city in Maryland, and the cities of Norfolk, Portsmouth, Virginia Beach, Hampton, and Chesapeake in the Tidewater region of Virginia have around 156,400 jobs exposed in 2050, accounting for 59 percent of the region's total flood-exposed jobs.

4 See Table A1 in the Appendix for the full list of counties.

In terms of the share of jobs affected, low-lying Somerset County, on the Eastern Shore of the Bay, and Worcester County, which borders the Atlantic Ocean, are most at risk in Maryland. Thirty-one percent of Somerset County jobs are exposed to flooding in current conditions and 36 percent by 2050. Worcester has 17 and 32 percent, respectively. In Virginia, several Tidewater jurisdictions have the greatest share of jobs affected. The city of Poquoson has 62 percent of its jobs currently at risk and more than 90 percent in 2050. Several Virginia jurisdictions will see more than 25 percent of their jobs exposed to flooding by 2050.

We also see heterogeneity across jurisdictions in the wages of jobs at risk. When we group jobs into high-, medium-, and low-wage categories, Baltimore, Norfolk, and Portsmouth have mostly high-wage jobs at risk. In the more tourist-oriented communities of Worcester County, Maryland, and Virginia Beach, Virginia, low-wage jobs are the most flood exposed.

We identify 44 census tracts in the Chesapeake Bay region that have both a high share of jobs at risk from flooding in 2050 and high social vulnerability. These include several communities along Maryland's eastern shore, particularly in Somerset County, and in Virginia's Hampton Roads. When vulnerable populations have a high share of nearby jobs exposed, this can be problematic for several reasons, such as negative impacts on employment; disrupted access to local goods and services during flood events; and long-run risks that businesses will eventually relocate, causing an economic downturn.

Our 2050 projections make no assumptions about how businesses and jobs will change in different coastal locations. Rather, we use current data and assess exposure to flooding projected with SLR. Any such assumptions would be ad hoc without detailed economic modeling and empirical estimation to capture the complex interplay of business location decisions and the community's adaptation choices, which are beyond the scope of this paper. Our estimates, therefore, should be interpreted as the exposure level before adaptation behaviors and inform on where adaptation, including business relocation, is most needed.

Our findings have several implications for policy. First, county and municipal governments need to consider climate adaptation actions in the broad context of their local economies, understanding what businesses and jobs are most at risk. Second, our results suggest a need for coordination between state economic development programs and climate adaptation and resilience policies. Most states, including Maryland and Virginia, promote economic development through direct grant funding, tax incentives, and public–private partnerships, with programs often targeting specific communities by designating "enterprise" or "opportunity" zones. However, most coastal states are acutely aware of the growing problems associated with coastal flooding and SLR. Coastal communities will be less exposed to climate change if development and adaptation policies align.. Finally, our assessment of where the greatest risks intersect with the greatest social vulnerability provides information on what communities and neighborhoods need help the most.

2. Data and Methods

2.1. Mapping of 1-Year and 100-Year Floods in Current Conditions and 2050

To determine whether a business's location is flooded in specific events, we compare its elevation with the extreme water level (EWL) for each flood return period.[5] We examine both 1-year and 100-year return periods, though we focus primarily on the latter. Our procedure roughly follows NOAA Office for Coastal Management's SLR inundation mapping technique (2017) to represent flooding associated with tides and SLR.

Our study area consists of all Maryland and Virginia coastal counties and cities that contain a section of the Chesapeake Bay shoreline or Atlantic Ocean and are expected to be affected by SLR, as determined by the NOAA SLR Viewer. The 2022 Sea Level Rise Technical Report provides a set of EWLs for each tidal gauge along the coast (Sweet et al. 2022). We link each one to the nearest tidal gauge and use the EWLs from that gauge. We also use the digital elevation model data for coastal areas at three-meter spatial resolution from NOAA's SLR Viewer (NOAA Office of Coastal Management 2022b).

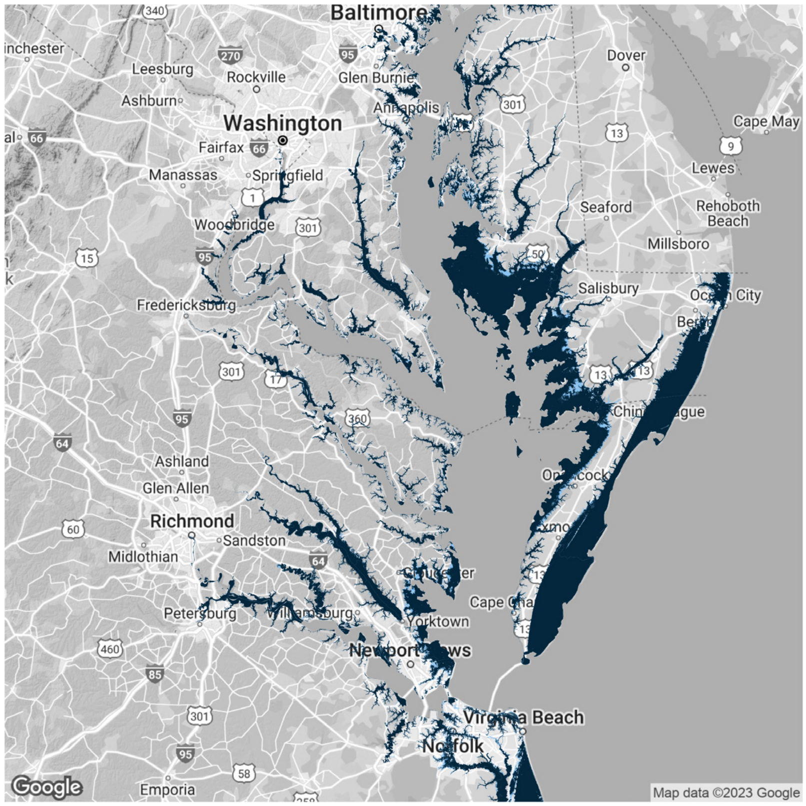
Following NOAA's recommended SLR inundation methods, we use GIS methods to add EWL to a modeled tidal datum surface (NOAA Office for Coastal Management 2022c). We then intersect this surface with the coastal digital elevation model, designate the largest contiguous surface as the ocean flood extent, and exclude disconnected inundation areas. Although these disconnected areas are low lying, they are not hydraulically connected to the ocean flood extent and likely will not be inundated by tidal EWL events. Finally, we derive 2050 flood risks by adding the height of regional mean SLR[6] to the county-level EWL and repeat the contiguous surface calculation to model future inundation. We apply a bathtub inundation method; the areas delineated represent an estimate of the potentially flooded areas for each EWL without considering local hydrodynamic processes, such as bottom friction, wave setup, and local wind-driven surge (Anderson et al. 2018; Garzon and Ferreira 2016).

Figure 1 plots the flood extent of a 100-year return period under current conditions and in 2050. The blue areas are locations that will be inundated now, and the light blue areas are additional locations that will be affected in the same scenario in 2050 due to

5 The return period is the expected average time between flood events; the inverse is the expected annual frequency of the event. Floods with a 100-year return period thus have a 1 percent chance of occurring each year, and floods with 1-year return period are expected to occur once a year. Each return period corresponds to an extreme water level (EWL). A higher EWL is less likely and thus associated with a longer return period.

6 Sea level rise values can be found in Table 2.2 of the Technical Report (Sweet et al. 2022).

Figure 1. Inundated Areas from 100-Year Flood in 2020 (Dark Blue) and 2050 (Dark Blue and Light Blue)



Note: Map produced using the ggmap package in R. For more information, see **https://journal.r-project.org/archive/2013-1/kahle-wickham.pdf**.

SLR. The map shows that many areas along the shoreline are subject to flood impacts in these scenarios, but the eastern shore of Maryland in particular has more at-risk land areas and is projected to see a bigger increase than the rest of the shoreline areas by 2050.

By overlaying the Coastal Change Analysis Program Regional Land Cover and Change dataset (NOAA Office for Coastal Management 2022d) with flooded areas, we calculate the total land area inundated in alternative tidal flood events now and with future SLR. The dataset also contains information on land classified as developed (and other land cover categories); we similarly compute the share of developed land in the Chesapeake region counties that will experience flooding (Table 1). The last row of the table shows the range of flood depths over the region, under current conditions and in 2050 with SLR.

Table 1. Flood Inundation Extent for the Chesapeake Bay Region Under Alternative Flood Return Periods, Current Conditions and 2050

		Current		2050 with SLR	
		1-year	100-year	1-year	100-year
Percent coastal land flooded	Maryland	7.8	11.6	9.5	13.9
	Virginia	6.8	10.6	8.0	11.9
	Total	7.3	11.1	8.8	12.5
Percent coastal developed land flooded	Maryland	1.2	3.3	2.0	4.3
	Virginia	1.3	5.3	2.3	7.9
	Total	1.3	4.2	2.1	6.0
Depth (feet)[7]	Total	0.5–2.6	3.9–8	1.8–3.9	5.2–9.3

A few findings are important to highlight. First, a lower percentage of developed land is flooded than total land, in both states and in all scenarios, because flooded lands are low-lying wetlands and other areas less suitable for development. Second, although Maryland has a larger land area affected by flooding in all scenarios, Virginia has a larger developed land area affected. Third, and related, Virginia's developed areas are more affected by SLR: by 2050, it is projected to increase flooding of developed land by 2.6 percentage points in Virginia (from 5.3 to 7.9 percent) but only 1 percentage point in Maryland (from 3.3 to 4.3 percent). Finally, although we focus on the areal extent of flooding and not flood depths, by 2050, flooded areas are projected to have approximately 5–9 feet of water in the 100-year event.

7 County-level flood depth is determined by matching county coastlines to the closest NOAA tidal gauge and using gauge-specific projections (Sweet et al., 2022).

2.2. Establishment, Employment, and Wage Income Data

To measure the impact of SLR on businesses and jobs, we use individual establishment data from the 2019 edition of the NETS Database, a 30-year panel of every individual US establishment. It is privately produced from Dun & Bradstreet (D&B) annual data and includes the location (latitude, longitude, and street address) of every establishment and its employment, estimated sales, industry (six-digit NAICS and eight-digit SIC codes), first year in business, and headquarters links, along with some additional information, such as whether it is minority or woman owned. The database has information on approximately 71 million establishments, 1990–2019 (see Appendix B). We combine the NETS employment data with average wage income data from the Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages at the industry and county level.[8] This gives us an estimate of total wage income for each establishment.

Table 2 summarizes the total establishments, employment, and wage income in the two states and their coastal counties and independent cities. The coastal jurisdictions are 37 percent of all counties and cities and 19.3 percent of total land area but a larger share of the economy: approximately 53 and 50 percent of all jobs and wage income, respectively, in the two states. Thus, the coast is an important driver of overall regional economic activity.

Table 2. Establishments, Employment, and Wage Income in the Chesapeake Bay Region

	Maryland		Virginia	
	Total	Coastal Counties	Total	Coastal Counties
Establishments (in millions)	0.56	0.35	0.71	0.29
Employment (in millions)	4.2	2.8	5.8	2.4
Wage Income (in billions)	$293.5	$189.4	$399.0	$158.8

Note: Authors' calculations using data from the NETS Database and BLS Quarterly Census of Employment and Wages.

8 **https://www.bls.gov/cew/**. Industry wages are provided at the six-digit NAICS code level but sometimes suppressed at the county level, particularly in small counties and where the industry accounts for a small number of establishments and jobs. In these cases, we use the state average wage income for that industry.

Based on the two-digit SIC code, we classify establishments into 10 industries.[9] We break down services, the largest industry, into seven categories: business services, personal services, education, health, hotel, recreation, and other.[10] Retail trade and government account for the greatest number of jobs in the region; several service categories are the next largest (business, health, other, education, and professional services, such as engineering). When we turn to wage income, government becomes the largest category, followed by professional services (engineering, accounting, etc.), and the finance, insurance, and real estate (FIRE) sector; business and health services make the fourth- and fifth-largest contributions. These differences between jobs and wage income reflect the different wage levels across industries. Although retail trade, for example, accounts for many more jobs than the business services and FIRE industries, retail jobs tend to be relatively lower paying. Overall, the economy in the Chesapeake Bay region is heavily oriented toward the service sector (as is true nationwide), though other sectors, such as manufacturing and construction remain important as well. We show the breakdown of jobs and wage income by industry in Appendix Figure A1 and Table A3.

9 **https://www.naics.com/sic-codes-industry-drilldown/**

10 The "other" category includes a wide variety of services, such as automotive and miscellaneous repair services, motion pictures, legal services, social services, membership organizations, and "not elsewhere classified."

3. Exposure of Jobs and Wage Income to Flooding

Table 3 presents the percent of exposed jobs and total wage income in the Chesapeake Bay region in a 100-year flood event: around 3.3 percent now and an additional 1.7 percent by 2050 if businesses remain in the same locations. Maryland has a lower exposure than Virginia—2.1 percent versus 4.8 percent in current conditions. By 2050, the difference grows, with an additional 0.9 percent of jobs in Maryland but an additional 2.6 percent in Virginia. This would amount to the exposure of approximately 83,900 jobs and $5.0 billion in wage income in Maryland and 179,567 jobs and $6.1 billion in wage income in Virginia by 2050.

Comparing these results with those in Table 1 for percent of developed land flooded, in Maryland, a smaller percent of jobs is flooded than developed land area (3 versus 4.3 percent in 2050 with SLR), but the Virginia shares are almost identical (7.4 versus 7.9 percent in 2050 with SLR). This suggests that the at-risk developed areas in Maryland may be primarily places where people live, but those in Virginia may be places where people both work and live.

These statistics represent the average exposure across the region, but they mask significant variation within the coastal areas. This is illustrated in Figure 2, which plots the exposure of jobs to 100-year floods by jurisdiction. The top panels present the percent of jobs exposed with Maryland counties on the left and Virginia counties and independent cities on the right, and the bottom panels present the absolute number of jobs in the same layout.[11] The dark and light blue bars represent exposure under current conditions and in 2050, respectively.

Table 3. Percent of Chesapeake Bay Region Jobs and Wage Income Exposed to 100-Year Flood in 2019 and in 2050 with SLR

	Current		2050, with SLR	
	Percent of Jobs	Percent of Wage Income	Percent of Jobs	Percent of Wage Income
Maryland	2.1	2.2	3.0	3.3
Virginia	4.8	4.8	7.4	7.3
Total	3.3	3.4	5.0	5.1

Note: Authors' calculations using data from the NETS Database and BLS Quarterly Census of Employment and Wages and methods described in the main text. All numbers in percentage terms. Results are for the 100-year return period. See Appendix for 1-year return period.

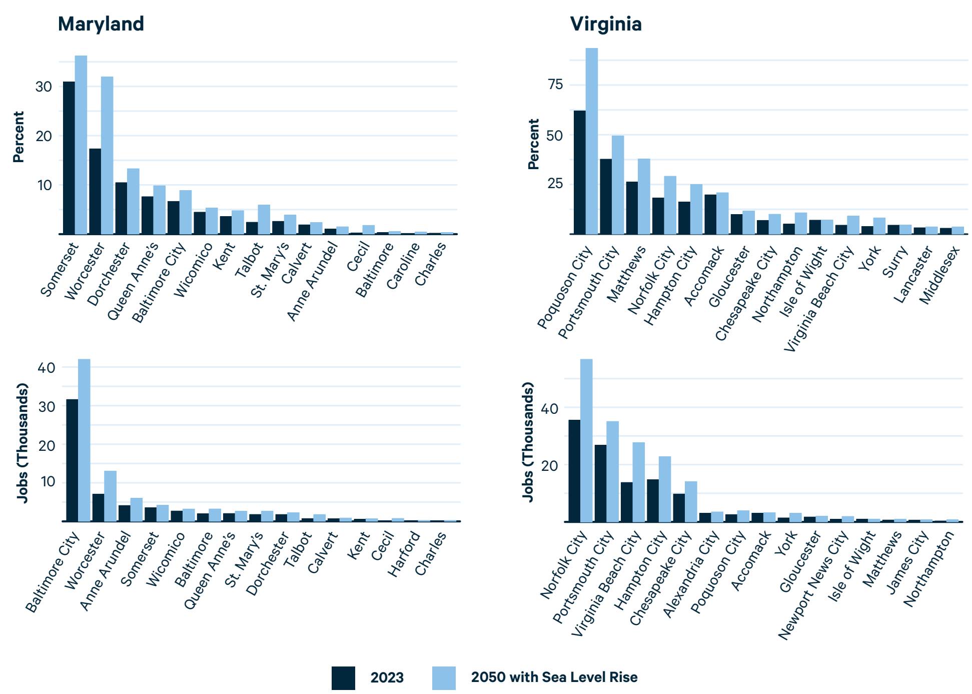
11 Virginia has 95 counties and 38 independent cities, which are not part of any county (and are administratively the same as counties). Maryland has only one independent city, Baltimore.

The top panels show that, in both states, counties and cities have heavy exposure. For example, Somerset in Maryland, a low-lying county on the lower eastern shore of the Chesapeake Bay, has more than 30 percent of jobs exposed in current conditions and more than 40 percent in 2050; Worcester County, Maryland's only county with direct ocean exposure, has 18 and more than 30 percent, respectively. The variation is even more pronounced across Virginia, where some independent cities and smaller counties are exposed to highly concentrated risk, such as Poquoson (62 percent), Portsmouth (38 percent), Mathews County (26 percent), Norfolk (20 percent), and Hampton (18 percent). All of these locations are in the Tidewater region in southeast Virginia. Most are also projected to see their numbers rise by over 10 percentage points by 2050. Poquoson is expected to reach more than 90 percent of its jobs at risk by 2050.

The bottom panels highlight the exposure in densely populated cities. For example, Baltimore city has 31,595 jobs exposed, more than half of all exposed jobs in Maryland. In Virginia, five cities (Norfolk, Portsmouth, Virginia Beach, Hampton, and Chesapeake) stand out with many more jobs exposed than the other jurisdictions. These cities are all projected to see a significant increase in the number of jobs exposed by 2050 due to SLR.

The spatial variation in exposure can also be seen at the census tract level in Figure A2. The percent of jobs exposed varies more widely across census tracts than counties or cities, as these smaller geographies can identify "hot spots" of concentrated risks. Although the areas most affected by SLR tend to be low-lying undeveloped land right

Figure 2. Percent and Number of Jobs Exposed to 100-Year Flood in Current Conditions and in 2050, 15 Local Jurisdictions



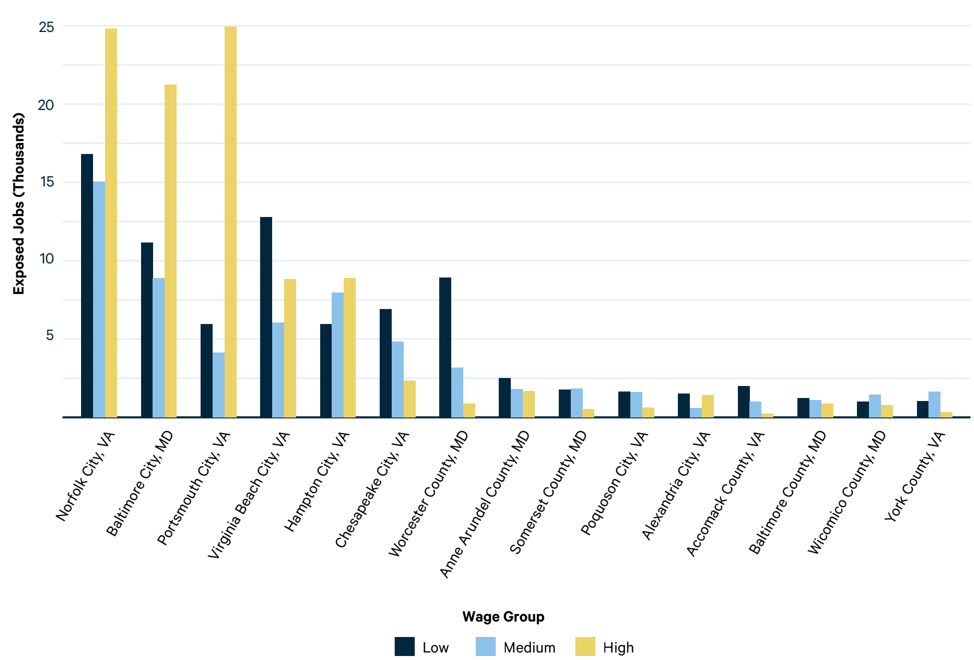
Note: This figure plots the top 15 counties/cities in Maryland and Virginia in terms of current exposure.

on the shoreline, some are home to many businesses facing increasing flood risk. In Figure A1, this is especially pronounced in several census tracts on the Eastern Shore of Maryland and Hampton Roads area in Virginia.

Figure 3 shows these flooding "hot spots," the top 15 counties and cities in terms of number of exposed jobs. These 15 counties are home to 294,885 establishments employing 2.58 million workers, 9.3 percent of which are exposed to 100-year flood risk in 2050. To examine exposure across wage income levels, we classify all jobs into "low," "medium," and "high," setting the thresholds between these categories to be the 33rd and 67th percentiles of the total wage income distribution across the two states, or $46,054 and $77,739, respectively. The figure shows the number of exposed jobs for each jurisdiction and by wage group. Cities and counties differ significantly in terms of the wage levels of exposed jobs. Norfolk and Portsmouth in Virginia and Baltimore in Maryland have more high-wage jobs with flood exposure than the other two groups, but the pattern is reversed in Virginia Beach and Chesapeake in Virginia and Worcester County in Maryland.

These heterogeneous patterns are largely driven by the different composition of industries in these locations. In Norfolk, for example, 22.5 percent of employment is relatively high-paying government jobs associated with the Norfolk Naval Station, Langley Air Force Base, and related establishments in the Tidewater region. Likewise, Portsmouth also has a large government sector (63.2 percent of jobs), and Baltimore has a sizable labor force in the FIRE industry (20.6 percent of jobs) and several high-paying service industries. On the other hand, retail trade and hotel services have the largest number of jobs exposed in Worcester County, making up just over half of employment. These industries have the lowest average wage levels in the economy. Appendix Table A3 provides the average wage for each industry in our sample.

Figure 3. Number of Exposed Jobs by Wage Group and Jurisdiction, in 2050



4. Social Vulnerability and Flood Exposure

The differences in wage income exposure to flooding across the region suggests that some households and communities could be especially vulnerable. Low-income households and communities have more limited financial resources and lower capacities to recover from disasters. Studies have found that lower-income and minority households are more at risk from flooding and that the problem will worsen with climate change (Wing et al. 2022). Similarly, studies have found that socially vulnerable populations—those that due to income, health status, linguistic isolation, and other factors suffer disproportionately from natural hazards—tend to inhabit high flood–risk areas (Lee and Jung 2014) and that several "hot spot" US areas have high vulnerability and high flood exposure (Tate et al. 2021). In this section, we conduct a similar analysis in our geographic setting, identifying the location of socially vulnerable populations and high flood–risk locations but with a focus on areas where jobs are at risk.

Our measure of vulnerability comes from the University of South Carolina's Hazards and Vulnerability Research Institute Social Vulnerability Index (SoVI). The index is designed to consider housing, social, and economic factors and assess community capacity to adapt to disasters (Cutter et al. 2003). Twenty-nine factors are evaluated at the census tract level, including income, age, employment, race, gender, and access to emergency services. The scale is then normalized from 0 to 100, with higher SoVI values indicating greater vulnerability to hazards.

The SoVI is based on where people live, not work, but our analysis of the combined effect of flood exposure of local jobs and social vulnerability of local populations could be important for three reasons. First, if employment opportunities closest to vulnerable populations are affected by flooding, it could make it more difficult for people to find a job nearby. Second, businesses might be disrupted during floods, creating problems accessing critical goods and services. Finally, if businesses move out of the community in response to flood risks, local populations will face greater inconveniences, such as longer commutes to work and reduced access to essential goods and services.

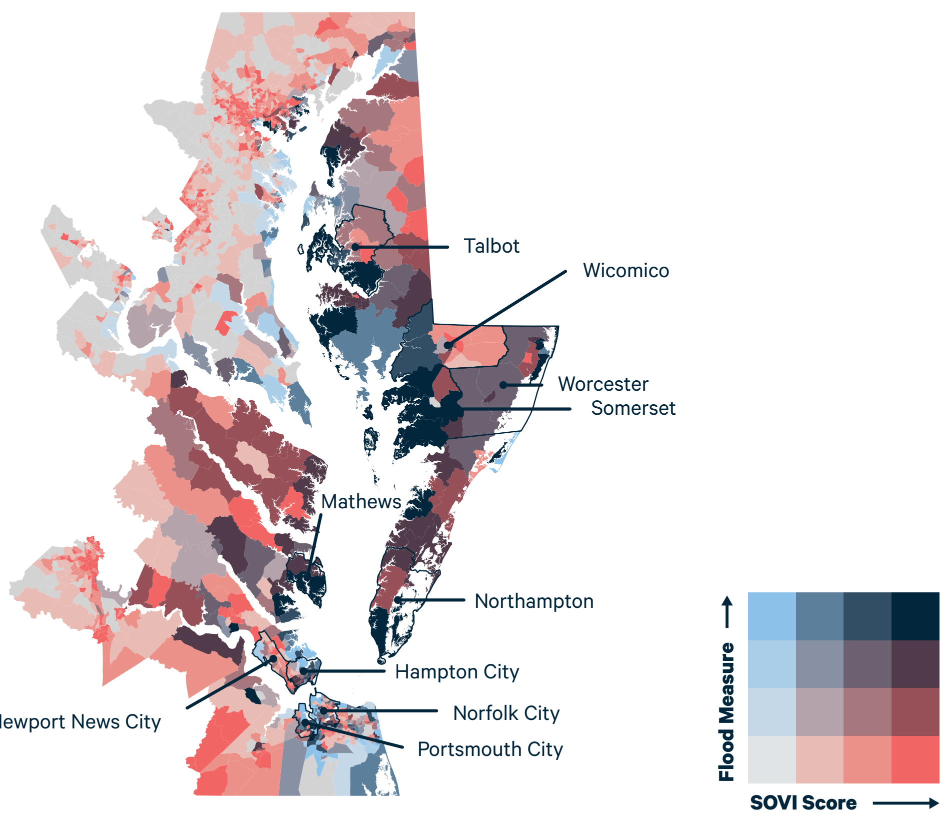
Figure 4 presents a bivariate map: shades of blue represent the share of jobs exposed to a 100-year flood in 2050,[12] and shades of red represent the quartiles of the SoVI. The dark brown areas represent the 44 census tracts that have the highest social vulnerability and the highest share of exposed jobs in a world with SLR. In Maryland, the tracts are concentrated on the eastern shore of the Bay, including Somerset County, parts of Talbot, Dorchester, Wicomico and Worcester Counties; the flood-exposed areas on the western shore tend to be less vulnerable. In Virginia, the map highlights Northampton County, on the eastern shore, which borders the Atlantic

12 The lowest category of the flood measure (the palest blue shade) contains all census tracts with no jobs exposed, and the remaining tracts are classified evenly into the next three categories.

Ocean and the Bay, and Mathews County, in the Tidewater region. Zooming in to the cluster of cities with high exposure in Tidewater, including Norfolk, Portsmouth, Hampton, and Newport News, tracts have significant heterogeneity within these cities: highly vulnerable tracts border less vulnerable tracts with similar flood exposure.

Table 4 provides demographic and industry statistics for this set of highly exposed and vulnerable census tracts in comparison with statewide averages. In general, these 44 tracts have about 30 percent lower median income than their respective states, higher poverty and unemployment rates, and a larger share of the population without a high school degree. The difference is more pronounced in Virginia than in Maryland. The lower portion of Table 4 provides the percent of employment for the five largest industries in these communities compared to statewide. Exposed and vulnerable census tracts in Maryland have a higher percentage of jobs in retail trade than the state as a whole, but the same is not true in Virginia, where the percentages are roughly the same for the exposed and vulnerable tracts and statewide. In both states,

Figure 4. Bivariate Map of 100-Year Flood Exposure in 2050 and Social Vulnerability



Notes: This map shows the spatial variation in flood exposure (in shades of blue) and SoVI score (in shades of red) across census tracts. The darkest blue tracts have the highest combined exposure and social vulnerability. Outlines (in black) and centroids (shown as dots) indicate select counties and cities that contain these tracts.

government jobs account for a smaller share of jobs in exposed and vulnerable tracts than statewide, but the differences are greater in Virginia.

Table 4. Demographics and Industry Composition Statewide vs. in Flood-Exposed and Socially Vulnerable Census Tracts

	Maryland	Exposed and vulnerable tracts in MD	Virginia	Exposed and vulnerable tracts in VA
Demographic characteristics				
Median income	$44,610	$31,278	$40,886	$27,875
Poverty rate (percent)	9.2	14.0	10.5	22.1
Percent of population w/o high school degree	9.8	13.0	10.3	14.6
Unemployment rate (percent)	5.0	6.1	4.5	7.9
Percent of jobs by selected industries				
Retail trade	15.4	19.8	16.2	15.8
Other services	8.2	7.3	7.8	13.7
Manufacturing	5.3	7.0	7.2	12.4
Government	12.2	11.2	9.1	5.9
Health services	9.7	6.6	7.6	10.5

Note: demographic statistics are based on the five-year estimates from the 2019 American Community Survey. Industry statistics are from the NETS Database.

5. Policy Discussion

Our findings suggest that an increasing number of jobs in the Chesapeake Bay region are at risk from flooding in a future with SLR and the problems are acute in specific hot spots. This suggests a need for resilience planning and investments coordinated and aligned with economic development policies.

The Federal Emergency Management Agency (FEMA) (2022) highlights the need for such coordination. The study focuses on coordinating Community Economic Development Strategies (CEDS), which are created by regional economic development organizations to access funding from the US Economic Development Administration, with hazard mitigation and resilience planning, which are handled by emergency managers and other local government officials, often with assistance from FEMA. The report includes specific recommendations for coordinating what are essentially two different kinds of planning exercises carried out by different governmental (or quasi-governmental) bodies, including recommendations regarding data collection, stakeholder engagement, and evaluation frameworks. It also recommends incorporating the risk and vulnerability assessments common in resilience into the required "economic resilience" component of CEDS.

CEDS developed in the Chesapeake Bay region differ in how much they align with the FEMA recommendations. For example, the Hampton Roads CEDS and the Lower Eastern Shore of Maryland CEDS both represent regions with significant risks from SLR and many businesses at risk. Hampton Roads covers the cities of Norfolk, Poquoson, Virginia Beach, and several other jurisdictions that our analysis identified as highly exposed; the lower eastern shore of Maryland includes the three flood-prone counties of Somerset, Wicomico, and Worcester. The Hampton Roads CEDS' strengths, weaknesses, opportunities, and threats (SWOT) analysis[13] emphasizes the threats posed by SLR and natural disasters, and its economic resilience strategy includes several suggestions for improving resilience to flooding, including improved development practices (Hampton Roads Alliance 2022); it mentions rising sea levels 44 times. The Lower Eastern Shore of Maryland CEDS, by contrast, only includes SLR and natural disasters as "threats" in a bulleted list, with no accompanying discussion or potential solutions (Tri-County Council for the Lower Eastern Shore of Maryland 2022).

Planning exercises and documents are important, but so is aligning funding and financial incentives. In the remainder of this section, we describe the resilience and economic development programs in Maryland and Virginia that provide funding and offer suggestions for how incentives across the two efforts might be aligned.

13 The US Economic Development Administration requires that CEDS include this analysis.

5.1. Resilience

One of the most significant developments on the resilience side in recent years is the establishment of revolving loan funds, which can be supported by federal dollars. The 2021 STORM Act (P.L. 116-284) authorized FEMA to make capitalization grants to these funds through the Safeguarding Tomorrow Revolving Loan Fund program. The November 2021 Infrastructure Investment and Jobs Act gives this program $500 million over five years.[14] Both Maryland and Virginia have positioned themselves for this potential infusion of funding with legislation to set up state resilience funds. Maryland passed its law in March 2021, mandating an appropriation of $5 million annually. In January 2023, the Maryland Department of Emergency Management, which will run the program, announced $25 million in low-interest loans for local governments and a goal of 40 percent of the loans going to underserved communities.[15] Virginia's law passed in January 2022, and the fund was seeded with $25 million from Regional Greenhouse Gas Initiative (RGGI) proceeds.[16]

RGGI money had gone to the Community Flood Protection Fund in Virginia, which the governor has announced will be replaced by the new resilience fund. The CPFP provided $65.4 million in grants to local communities in 2022, 82 percent of which went to communities in coastal areas.[17] It funded projects to upgrade stormwater management systems, erect floodwalls, install living shorelines, and other structural upgrades, as well as many planning and assessment studies. Maryland's Department of Natural Resources also operates resilience grant funding programs, using a combination of state and federal funding. In July 2022, it announced more than $2 million in Climate Resilience Grants to 12 communities.[18] Most of this funding went to development of plans and designs for projects rather than actual construction (which is not surprising given the relatively low level of funding).

Finally, in a unique approach, Maryland passed a law in 2020 that authorizes the establishment of local resilience authorities, which facilitate flexible financing and management of large-scale infrastructure projects, including through public–private partnerships. Resilience authorities can charge and collect fees for services and issue tax-exempt bonds for projects, all separate from county and city governments. Thus far, Anne Arundel County and Charles County, both on the Chesapeake Bay, have established such authorities.

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14 In August 2022, FEMA announced the first round of funding to allocate $50 million, calling for proposals by May 2023.

15 **https://news.maryland.gov/mdem/2023/01/11/maryland-department-of-emergency-management-makes-up-to-25-million-available-to-local-jurisdictions-for-disaster-resiliency-projects/**.

16 RGGI is a cap-and-trade program to reduce carbon dioxide emissions from the electricity sector that includes participation by 12 northeastern states (including Maryland and Virginia).

17 **https://www.dcr.virginia.gov/dam-safety-and-floodplains/dsfpm-cfpf-awards**.

18 **https://news.maryland.gov/dnr/2022/07/27/maryland-awards-climate-resilience-grants-to-12-communities/**.

5.2. Economic Development

Most states have well-established programs to improve local business environments and encourage job creation, and Maryland and Virginia are no exception. The Maryland Department of Commerce spent approximately $178 million on grants, loans, and tax incentives for business and job creation in (FY) 2021 across 55 separate programs.[19] According to a report on the performance of 20 of these programs for the same year, the state spent $91.7 million creating 16,892 new jobs.[20] Virginia spent $385 million in economic development programs in FY2020.[21]

As the coastal counties in these two states are home to over half of the states' jobs, it is no surprise that a significant share of this spending flows to the coastal economy. Of the FY2021 spending in Maryland, we were able to identify $65.9 million in county-targeted incentives; $57.8 million (88 percent) went to coastal counties. In Virginia, we could identify the location of $60.7 million in direct incentives spent in FY2018 through the Virginia Economic Development Partnership; $23.4 million (39 percent) went to coastal counties.[22,23] Table A4 in the Appendix lists each of the programs and their individual funding levels.

Economic development spending is often targeted, through the creation of enterprise zones, to communities that have experienced economic decline or lag behind others in the state.[24] Maryland has 34 enterprise zones in 19 jurisdictions; 12 of these jurisdictions are in the Chesapeake Bay region, and several are in areas that will be hard hit by SLR.[25] Virginia has 45 enterprise zones, 10 in the Chesapeake Bay region.[26] Many of these coincide with the areas we identified as having the highest social vulnerability.

19 **https://commerce.knack.com/maryland-funding-incentives**. The FY2021 budget for the Department of Commerce can be found at **https://dbm.maryland.gov/budget/Documents/operbudget/2022/agency/DepartmentofCommerce.pdf**.

20 **https://commerce.maryland.gov/Documents/ProgramReport/maryland-jobs-development-act-executive-report-FY21.pdf.**

21 See **http://jlarc.virginia.gov/pdfs/reports/Rpt557.pdf.**

22 Many of the tax incentives flow to the tobacco-growing and coal fields regions of the state, which are not coastal, and to data centers, which are located around the state but concentrated in Northern Virginia (**https://www.vedp.org/industry/data-centers**).

23 See **https://www.virginiaincentives.org/**. Although the most recent data are from 2019, we find that year to be an anomaly with a $750 million special grant for Amazon, which located its second headquarters in Virginia.

24 Opportunity zones are another geographic designation. These are economically disadvantaged areas that are eligible for federal tax incentives. See **https://www.irs.gov/credits-deductions/opportunity-zones-frequently-asked-questions**. A map of opportunity zones in the Chesapeake Bay region can be found at **https://chesapeake-deij2-chesbay.hub.arcgis.com/apps/6aabd978f3b64f8f8450e6b361e5deaa/explore**.

25 Maryland's enterprise zone map is available at **https://commerce.maryland.gov/Documents/BusinessResource/maryland-enterprise-zone-map.pdf**.

26 and Virginia's is at **https://www.dhcd.virginia.gov/sites/default/files/Docx/vez/2019-enterprise-zone-map.pdf.**

5.3. Aligning Climate Resilience and Economic Development Policies

Economic development and climate resilience programs mostly operate independently. Our findings here emphasize a need for integration. Some possibilities include the following:

- A portion of resilience spending, including through the new revolving loan funds that receive federal dollars, could be used to support relocating businesses out of flood zones and areas projected to be flood-exposed with SLR. This does not mean that businesses need to relocate away from coastal communities, just that they seek higher ground and more protected locations within those communities.
- States can stipulate that grants and tax credits in economic development programs be directed to creating new jobs outside of flood zones and/or areas expected to be hardest hit by SLR. Again, this does not mean that economic development dollars be directed away from coastal communities. Instead, a condition of the grants should be that new businesses must locate in less flood-exposed areas.
- Some flood-prone regions are envisioning their economies as built around leadership on flood mitigation, water management, and resilience, such as Hampton Roads in Virginia. Its CEDS lists SLR as both an opportunity and a threat in the SWOT analysis because it allows the region to develop its expertise and an industrial cluster in "Water Technologies" (Hampton Roads Alliance 2022). State economic development activities could prioritize supporting businesses in this sector with a stipulation that flood-prone communities in the state reap some of the benefits in the form of resilience projects.[27]
- Communities, such as Norfolk, that adopt climate-informed zoning could be prioritized for resilience and economic development spending. In 2018, the city adopted a zoning overlay that aims to direct long-term growth to less risky areas (City of Norfolk 2022). The new code divides the city into different zones based on a resilience overlay and encourages different development patterns and mitigation measures based on the level of risk in each zone.
- Economic development spending in enterprise zones that are highly flood exposed can incorporate resilience criteria, such as requiring and supporting building elevation and other modifications that reduce flood losses or enhance flood preparedness. Maryland already has Priority Funding Areas, which are used to target state spending to localities that meet requirements on density and water and sewer services provision (Lewis et al. 2009). Adding adaptation and resilience measures to the list may be warranted.

27 In Louisiana, state economic development activities have been emphasizing the state's relative strengths in the industry of "water management." According to its Economic Development Authority, 118,370 people work in water management–related professions in the state, and the industry is projected to grow by 23.4 percent over the next decade. **https://www.opportunitylouisiana.gov/eq/q2-2017/making-waves**.

6. Conclusion

Our findings show that multiple communities in the Chesapeake Bay region face substantial flooding exposure to their businesses and jobs, and the physical risks will continue to rise in the next few decades. However, the region has great heterogeneity, with some communities much harder hit and some more socially vulnerable. These patterns and trends call for targeted adaptation measures to curb the continued growth in exposure and enhance the overall resilience of the coastal economy in Maryland and Virginia. Economic development spending is an opportunity to build resilience, and resilience spending is an opportunity to enhance the economic viability of coastal communities. We suggest multiple ways to make economic development and resilience planning compatible. Further research into the feasibility and effectiveness of these approaches is warranted.

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8. Appendix A: Additional Tables and Figures

Table A1. Coastal Counties in the Chesapeake Bay Region

County	Businesses	Jobs
Anne Arundel County, Maryland	48,088	398,505
Baltimore city, Maryland	45,663	474,684
Baltimore County, Maryland	69,728	586,004
Calvert County, Maryland	6,296	37,090
Caroline County, Maryland	2,293	12,718
Cecil County, Maryland	6,221	43,030
Charles County, Maryland	11,689	72,615
Dorchester County, Maryland	2,352	17,041
Harford County, Maryland	18,045	152,812
Howard County, Maryland	31,664	249,389
Kent County, Maryland	1,856	14,889
Prince George's County, Maryland	78,579	540,882
Queen Anne's County, Maryland	4,886	26,830
Somerset County, Maryland	1,265	11,513
St. Mary's County, Maryland	6,375	68,976
Talbot County, Maryland	4,386	30,090
Wicomico County, Maryland	7,366	60,156
Worcester County, Maryland	6,161	40,849
Accomack County, Virginia	2,015	15,580
Alexandria city, Virginia	16,589	154,657
Arlington County, Virginia	21,973	245,129
Charles City County, Virginia	558	2,891

Chesapeake city, Virginia	18,702	140,626
Chesterfield County, Virginia	28,425	202,825
Colonial Heights city, Virginia	1,547	12,873
Essex County, Virginia	748	5,387
Falls Church city, Virginia	2,392	15,040
Franklin city, Virginia	698	5,820
Gloucester County, Virginia	2,612	17,465
Hampton city, Virginia	9,202	91,404
Hopewell city, Virginia	1,151	11,748
Isle of Wight County, Virginia	2,602	14,177
James City County, Virginia	6,640	45,824
King and Queen County, Virginia	389	1,973
King George County, Virginia	1,712	13,545
King William County, Virginia	1,088	6,244
Lancaster County, Virginia	1,133	7,348
Mathews County, Virginia	498	2,596
Middlesex County, Virginia	802	4,624
New Kent County, Virginia	1,651	8,440
Newport News city, Virginia	12,494	142,129
Norfolk city, Virginia	16,540	194,668
Northampton County, Virginia	928	7,077
Northumberland County, Virginia	965	5,033
Petersburg city, Virginia	2,350	26,118
Poquoson city, Virginia	876	4,153
Portsmouth city, Virginia	6,102	70,981
Prince George County, Virginia	1,783	19,192
Prince William County, Virginia	36,492	225,339
Richmond city, Virginia	21,568	235,675

Richmond County, Virginia	488	6,090
Stafford County, Virginia	10,421	61,634
Suffolk city, Virginia	6,303	43,955
Surry County, Virginia	395	2,237
Virginia Beach city, Virginia	42,160	305,503
Westmoreland County, Virginia	1,165	6,024
Williamsburg city, Virginia	1,272	22,236
York County, Virginia	4,852	36,912
Total	**643,194**	**5,279,245**

Table A2. Percent of Chesapeake Bay Region Jobs and Wage Income Affected by One-Year Flood Event in 2019 and in 2050 with Sea Level Rise

	2019		**2050, with sea level rise**	
	Jobs	**Wage Income**	**Jobs**	**Wage Income**
Maryland	0.13	0.11	0.56	0.48
Virginia	0.25	0.20	0.75	0.63
Total	0.19	0.15	0.65	0.55

Table A3. Average Annual Wage by Industry in Chesapeake Bay Region

Industry	Average annual wage
Agriculture, Forestry, Fishing	$45,758
Construction	$68,678
Finance, Insurance, Real Estate	$103,543
Government	$92,203
Manufacturing	$81,861
Retail Trade	$30,336
Services—Business	$66,623
Services—Education	$55,151
Services—Engineering, etc.	$100,503
Services—Health	$66,758
Services—Hotel	$30,077
Services—Other	$52,983
Services—Personal	$32,968
Services—Recreation	$36,830
Transportation and Public Utilities	$73,230
Wholesale Trade	$73,039
Overall	$66,116

Table A4. Business Incentives, Including Tax Credits, Grants, and Loans, in Virginia and Maryland

State	Program	Total Incentives (Thousands of $)	Percent to Coastal Counties
MD	Advantage Maryland (MEDAAF)	$5,315	90
	Buy Maryland Cyber Tax Credit	$346	99
	E-Nnovation	$7,550	87
	Hire Our Veterans Tax Credit	$7.2	100
	Job Creation Tax Credit	$1,714	78
	Military/Veterans Small Business Loans*	$75	100
	More Jobs for Marylanders	$1,277	48
	MSBDFA Program*	$14,758	82
	NIMBL*	$75	100
	One Maryland Tax Credit	$5,000	100
	PWQ	$621	60
	R&D Tax Credit	$15,000	100
	SBRTC	$2.1	100
	SMWOBA VLT Fund*	$14,130	81
MD	Total	$65,871	88
VA	Agriculture and Forestry Industries Development Fund	$862	12
	CIT GAP Funds	$2,239	29
	Commonwealth's Development Opportunity Fund	$12,003	58
	Economic Development Access Program	$3,100	0
	Governor's Motion Picture Opportunity Fund	$3,400	31
	Job Creation Grant†	$2,050	63
	Port of Virginia Economic and Infrastructure Development Grant	$508	6.1

	Rail Industrial Access Program	$1,788	25
	Real Property Investment Grant†	$10,673	55
	Tobacco Region Opportunity Fund	$5,913	0
	Virginia Economic Development Incentive Grant	$4,000	0
	Virginia Investment Performance Grant	$4,400	77
	Virginia Jobs Investment Program	$9,812	38
VA	Total	$60,746	39
Both	Total	$126,617	64

* Primarily an interest-free loan program.

† Grants reserved for Virginia Enterprise Zones.

Note: Data from this table are drawn from the Maryland Consolidated Incentives Performance Report for FY2021 and Virginia Economic Development Partnership data for FY2018 (the most recent year with nonanomalous data). These figures are representative of the programs included in the table but may not capture the entirety of economic development incentives distributed by Maryland and Virginia.

Figure A1. Coastal Employment and Wage Income by Industry and State

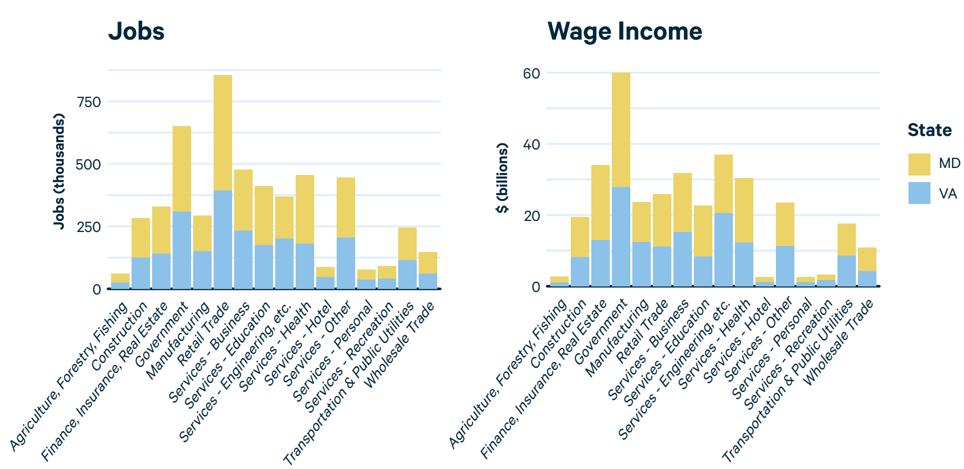
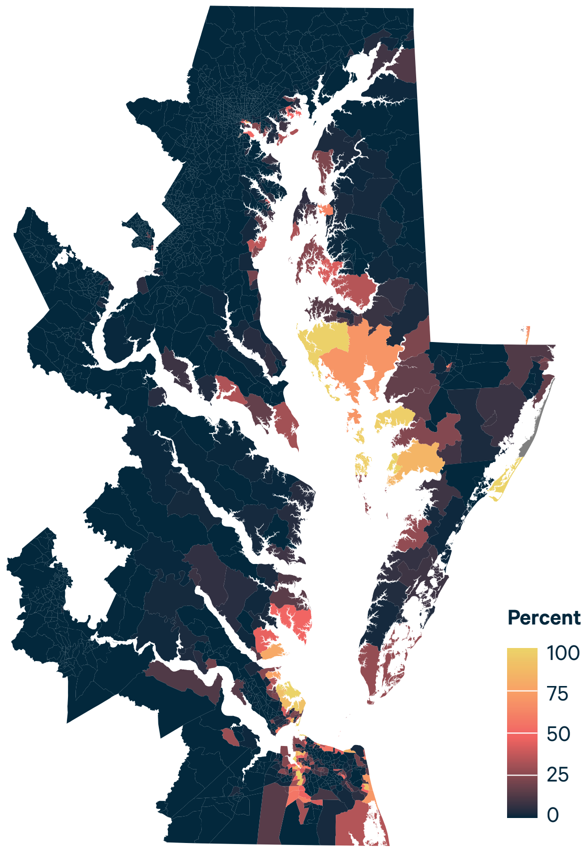


Figure A2. Percent of Jobs Exposed to 100-Year Flood in 2050 by Census Tract



9. Appendix B: Information on the NETS Database

Walls & Associates produces the NETS Database each year from Dun and Bradstreet (D&B) data. The D&B data collection process is a large annual undertaking that includes phone calls, media and news reports, company filings, and Internet searches. D&B issues a DUNS number that is unique to each establishment, which stays the same when it moves location and is never reused if it goes out of business. As pointed out by Neumark et al. (2007) and Asquith et al. (2019), many businesses' access to credit and ability to enter business relationships depend on D&B ratings and Paydex (credit) scores, which depend, in turn, on the quality of the information gathered by D&B. Thus, D&B has a strong business incentive to collect reliable data. Walls & Associates produces the NETS longitudinal database, issuing a new release each year and ensuring consistency in the panel data.

NETS is similar to the US Census Bureau's Longitudinal Business Database (LBD), restricted-use longitudinal establishment-level microdata constructed from the Census Bureau's Business Register. Unlike LBD, however, it can be used anywhere with purchase of a license and is not subject to highly restrictive confidentiality and disclosure requirements. NETS and LBD do differ in some ways. LBD covers only private nonfarm businesses, whereas NETS includes all establishments, private and public. NETS also includes self-employed workers and sole proprietors. In comparisons with the public government datasets from the Census Bureau and BLS, studies have shown that NETS includes more establishments overall, generally because it has more small businesses (Neumark et al. 2007; Barnatchez et al. 2017). For our purposes, to capture effects in small towns and rural areas of the Chesapeake Bay, we consider that NETS is comprehensive and includes small businesses to be more of a strength than a weakness.

NETS has been used in a wide range of peer-reviewed studies, such as analyses of the effects of trade with China on US job flows (Asquith et al. 2019), enterprise zone impacts on job creation (Neumark and Kolko 2010), fast food restaurants effects' on obesity (Currie et al. 2010), the effects of national monument designations on job and wage growth in the western United States (Walls et al. 2020), the role of small business in job creation (Neumark et al. 2011), and the effects of wildfires on job growth in western US communities (Walls and Wibbenmeyer 2023).