ESTIMATING THE ECONOMIC IMPACT OF A NATURAL DISASTER ON THE WORKFORCE RESILIENCY:
An Analysis of the Virginia Beach - Chesapeake – Norfolk Metropolitan Statistical Area

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Abstract and Keywords

In this paper, we explore the potential economic impacts associated with a major hurricane making landfall in Hampton Roads. We estimate the direct damages from a Florence-like Category 3 hurricane with a 3.6 feet tidal offset are estimated at $15.6 billion, equivalent to 10% of the 2022 regional GDP. If we apply existing flood insurance rates to these projected damages, we estimate that the total economic impact would exceed $12 billion with a short-term loss of more than 76,000 jobs. The job losses are concentrated in sectors that provide services to households which would bear the brunt of damages during and after a hurricane. Reducing financial damages by increasing flood insurance take up rates is a recommended policy action to improve economic resiliency in Hampton Roads.

Keywords: Sea level rise, Hurricane, Flood Insurance, Economic Losses, Loss estimation

Background and Introduction

While projections of future sea level rise are uncertain, there is increasing confidence that expected rises in sea level will increase the probability of extreme flooding events (Taherkhani et al., 2020). For regions prone to coasting flooding, including the Virginia Beach – Chesapeake – Norfolk ("Hampton Roads") metropolitan statistical area (MSA), future moderate and major high tide flood events will occur with the same frequency as present-day minor and moderate flood events (Sweet et al., 2017). Even if near-term climate change mitigation efforts succeed, sea level rise and its impacts will continue to rise in the coming decades (Masson-Delmotte et al., 2021).

Sea level rise results in the loss of land and damage to structures and infrastructure (Hallegatte, 2012). It also degrades human and social capital, lowers worker productivity, induces migration from flood-prone areas, and slows economic growth (Bosello et al., 2007; Gleditsch & Urdal, 2002; Pycroft et al., 2016). Sea level rise may amplify rainfall damages in coastal areas (Passeri et al., 2015). As stillwater elevation increases, there is an increased likelihood of moderate and severe flooding from storm events (Hsiang et al., 2017; Vellinga & Leatherman, 1989). Projecting the economic impacts associated with a significant storm event is an element of flood risk assessment and necessary to weigh the costs and benefits of potential courses of action to mitigate future flooding risks (Bowen & Riley, 2003; Meyer et al., 2009).

An economic impact analysis (EIA) estimates the impact of an event of specific duration and location on economic activity at the local, regional, or national level. The initial input into EIAs is typically an estimate of an event's direct impact on expenditures or payrolls. These direct impacts 'ripple' through the study region, creating secondary (indirect) and tertiary (induced) impacts. Indirect economic impacts are supply-chain related impacts, that is, how the direct impacts impact suppliers in the study area. Induced economic impacts are generated by the increases (or decreases) in compensation and household incomes. Communities outside the affected localities may still be impacted through linkages with the impacted localities. While methodologies may vary, EIA analyses typically estimate changes in industry production (output), value added (Gross Domestic Product), employee compensation, and nonfarm payrolls (jobs). These impacts may be presented in nominal or discounted dollars, depending on the study's time horizon and scope.

This paper builds upon previously completed work in 2019 regarding the economic impact of a Category 3 hurricane making landfall in the Hampton Roads region. The primary focus of the previous work was to inform policymakers of the magnitude of the economic shock associated with a major hurricane making landfall in the metropolitan area. Thus, the workforce estimates did not examine what elements of the labor market would be most significantly impacted and which elements of the labor market would likely be most (and least) resilient in the aftermath of a major hurricane making landfall in Hampton Roads. The question of how the region might recover over time was left for future research, due to resource and time constraints. Understanding the economic resiliency of the workforce and how the composition of the regional economy would likely influence the pace and breadth of the recovery is important for planning and the future allocation of resources.

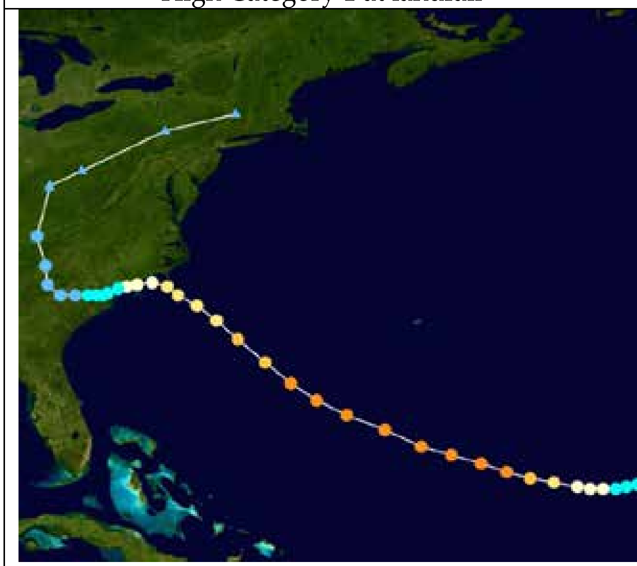
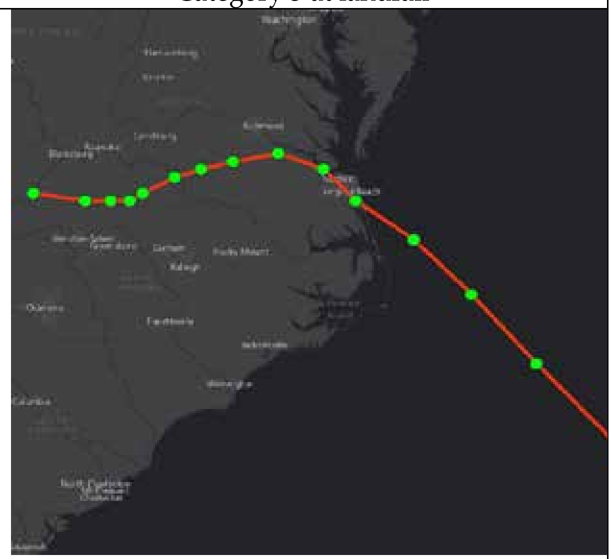
Surveys of the economic impact of sea level rise and recurrent flooding have noted significant heterogeneity in approaches and results (Amelung et al., 2007; Arabadzhyan et al., 2021). While direct damages to structures and infrastructure can be modeled with reasonable fidelity, indirect and induced losses are inherently dynamic. Measures of natural resource, human capital, and social capital endowments are imprecise and are typically not estimated frequently (Yu et al., 2024). Local and regional responses to changes in employment, expenditure, or fiscal policy are heterogenous to the event. State or national level studies impose response homogeneity which implicitly assumes there are no gains or losses in allocative efficiency. Adaptation to sea level rise is also local, heterogenous, and dynamic and may interact with mitigation efforts (Tol, 2005). Improving resiliency may also generate externalities that are not readily captured by EIAs. Finally, EIAs are dependent on the underlying assumptions which can be manipulated to generate a more favorable set of estimates (Crompton, 2006).

Estimating The Physical Damage from A Hurricane

Estimating the physical damage from a major storm is a journey in uncertainty. Every weather event is unique, and the estimates from any model are a product of the underlying assumptions. To explore the potential physical damages from a hurricane striking Hampton Roads, we modified the track and strength of Hurricane Florence (2018), where the modified Category 3 storm makes landfall near the Virginia-North Carolina border (Table 1). We model the wind and water damages from the modified Category 3 storm using Hazus, a standardized set of tools and data from the Federal Emergency Management Agency (Federal Emergency Management Agency, 2022; Ghimire & Sharma, 2021; Scawthorn et al., 2006; Schneider & Schauer, 2006). The Hazus model generates estimates of wind and storm surge damage.

The direct damages from the hurricane are dependent on the projected water level along the coast during the hurricane. Recurrent tidal flooding, often called 'nuisance' flooding, influences the potential damages from a hurricane. Nuisance flooding is defined as a water level measured by National Oceanic and Atmospheric Administration (NOAA) tide gauges above the local NOAA National Weather Service (NWS) threshold for minor impacts established for emergency preparedness. The nuisance flooding threshold level for Norfolk, Virginia, was estimated to be 0.53m (~1.74ft) above mean higher high water (MHHW) datum and predicted an accelerating trend of tidal flooding days per year (Sweet, Marra, et al., 2017). The difference between tidal datums mean sea level (MSL) and MHHW varies slightly depending upon location (0.42 to 0.585 meters or 1.7 to 1.9 feet), with higher differences being found along the Atlantic coastline in Virginia Beach, Virginia. We add the nuisance flooding value to the higher end of the MHHW datum to obtain the 3.6 feet tidal offset that is used as the baseline for modeling the flooding impacts of the Florence-like hurricane. We also estimate water damages for a 6.6-feet tidal offset to explore how sea level rise would impact the damages associated with a Category 3 hurricane making landfall in the Hampton Roads metropolitan area.

Table 1.
Modifying Florence to Impact Hampton Roads

Hurricane Florence Landfall: Near Wilmington, North Carolina Storm Surge: 6 feet Rainfall: 30-plus inches Speed at Landfall: slow High Category 1 at landfall	Modified Hurricane Track Landfall: Virginia-North Carolina Border Storm Surge: Category 3 Rainfall: 36 inches Speed at Landfall: slow Category 3 at landfall
	

Sources: NOAA (2018) and Hazus (2018). Storm surge in the modified track is generated using the Maximum Envelope of Water Category 3 scenario.

Table 2 presents the estimated wind and water damages by locality from a hurricane making landfall in Hampton Roads for a 3.6- and 6.6-feet tidal offset. We note that wind damages are assumed to be independent of the tidal offset. The Florence-like hurricane causes approximately $4.4 billion in wind damage throughout the metropolitan area. Estimated wind damages are highest in Norfolk ($794.6 million), Chesapeake ($740.9 million), and Hampton ($541.1 million) as the hurricane makes landfall near the Virginia – North Carolina border.

For a 3.6-feet tidal offset, we estimate that water damages are approximately $11.2 billion for the metropolitan area. Proximity to the water and elevation influence the magnitude of direct water damages. Norfolk ($3.9 billion), Hampton ($2.6 billion), and Poquoson ($1.8 billion) account for approximately 74.0% of projected water damages in the region from a hurricane making landfall with a 3.6 feet tidal offset. In total, the combined direct damages given a 3.6 feet tidal offset are equal to approximately $15.6 billion, roughly equivalent to 10% of 2022 regional Gross Domestic Product (GDP).

For a 6.6 tidal offset, water damages increase to approximately $33.2 billion. For Norfolk, water-related damages increase from $3.9 billion to $13.1 billion. Hampton's damages increase from $2.6 billion to about $6.0 billion. Chesapeake, which was estimated to have $211.8 million in water damages with 3.6 feet of offset, observes an increase in water-related damages to approximately $4.0 billion. A 6.6 tidal offset would result in total damages equivalent to 32.3% of 2022 regional GDP.

Table 3 illustrates the projected damages by building occupancy type for a Florence-like hurricane making landfall on the Virginia – North Carolina border with 3.6 feet tidal offset and a 6.6 feet tidal offset. Residences account for approximately $3.5 billion of the projected $4.4 billion in wind damages, followed by buildings with commercial occupancy uses ($496.4 million). In other words, single and multi-family residences account for 79.1% of projected wind damages from a Category 3 hurricane making landfall in Hampton Roads.

With a 3.6 feet tidal offset, water-related damages to buildings with residential occupancy are approximately $7.5 billion or 67.1% of all water-related damages. When the projected tidal offset rises to 6.6 feet, water-related damages to buildings with residential occupancy rise to $20.5 billion. The share of damages for residential buildings falls from 67.1% (3.6 feet tidal offset) to 61.8% (6.6 feet tidal offset) due to the rise in damages in other occupancy types. Buildings with commercial occupancy uses observe an increase in projected water-related costs from $496.4 million to $6.4 billion. Building with educational occupancy uses see a rise in projected water-related costs from $672.7 million to $2.6 billion.

Given the magnitude of damages from a 6.6 feet tidal offset, we provide these estimates for information and focus on the damages associated with a 3.6 feet tidal offset. Our argument is straightforward: the 6.6 feet tidal offset represents the 'worst of the worst' modeling outcomes. If sea level rise occurs as projected, then the 6.6 feet tidal offset is likely to become the reference scenario in the future. Costs of such magnitude would likely have a devastating impact on the region, regardless of the resiliency of the workforce to economic shocks. In other words, a natural disaster wreaking havoc roughly equal to one-third of regional GDP would likely overwhelm regional, state, and federal preparation and recovery efforts, reducing potential economic activity in the region for years to come. With this in mind, we focus our efforts on the present and the question of the impact of the 3.6 feet tidal offset scenario on the workforce in Hampton Roads.

Table 2.
Expected Wind and Water Damages by Locality Category 3 Hurricane Striking Hampton Roads

Locality	Wind Damage (Thousands of Dollars)	Water Damage (Thousands of Dollars) (3.6 Feet Tidal Offset)	Water Damage (Thousands of Dollars) (6.6 Feet Tidal Offset)	Total Damages (Thousands of Dollars) (3.6 Feet Tidal Offset)	Total Damages (Thousands of Dollars) (6.6 Feet Tidal Offset)
Chesapeake	$740,868	$211,823	$3,975,378	$952,691	$4,716,246
Franklin	$6,293	$0	$0	$6,293	$6,293
Gloucester	$151,197	$739,194	$1,254,237	$890,390	$1,405,365
Hampton	$541,132	$2,619,021	$5,995,777	$3,160,153	$6,536,907
Isle of Wight	$121,980	$44,901	$70,345	$166,881	$192,325
James City	$249,262	$21,829	$45,312	$271,091	$294,574
Newport News	$436,247	$26,198	$274,686	$462,445	$710,933
Norfolk	$794,595	$3,845,883	$13,117,002	$4,640,478	$13,908,898
Poquoson	$78,530	$1,800,744	$2,002,394	$1,879,274	$2,080,924
Portsmouth	$221,567	$955,066	$3,436,049	$1,176,633	$3,657,616
Southampton	$18,276	$0	$0	$18,276	$18,276
Suffolk	$206,288	$29,304	$47,847	$235,592	$254,135
Surry	$17,460	$5,348	$7,082	$22,808	$24,542
Virginia Beach	$380,145	$177,135	$1,199,986	$557,280	$1,580,131
Williamsburg	$34,426	$0	$0	$34,426	$34,426
York	$385,099	$767,400	$1,768,164	$1,152,499	$2,153,263
Totals	**$4,383,365**	**$11,243,846**	**$33,194,258**	**$15,627,211**	**$37,574,854**

Source: HAZUS (2024). Numbers may not sum to totals due to rounding.

Table 3.
Expected Wind and Water Damages by Occupancy Type
Category 3 Hurricane Striking Hampton Roads

Occupancy Type	Wind Damage (Thousands of Dollars)	Water Damage (Thousands of Dollars) (3.6 Feet Tidal Offset)	Water Damage (Thousands of Dollars) (6.6 Feet Tidal Offset)	Total Damages (Thousands of Dollars) (3.6 Feet Tidal Offset)	Total Damages (Thousands of Dollars) (6.6 Feet Tidal Offset)
Agriculture	$25,267	$16,977	$60,151	$42,244	$85,418
Commercial	$496,429	$1,839,702	$6,391,718	$2,336,131	$6,888,147
Educational	$174,287	$672,752	$2,581,382	$847,039	$2,755,669
Government	$30,646	$222,959	$703,557	$253,605	$734,203
Industrial	$157,406	$653,509	$2,047,271	$810,915	$2,204,677
Religion	$33,497	$297,833	$894,479	$331,330	$927,976
Residential	$3,465,832	$7,540,114	$20,515,701	$11,005,946	$23,978,764
Totals	**$4,383,365**	**$11,243,846**	**$33,194,258**	**$15,627,211**	**$37,574,854**

Source: HAZUS (2019). Numbers may not sum to totals due to rounding.

Economic Impact Methodology

One possible approach to estimating the economic impacts associated with a natural disaster is the use of a Computable General Equilibrium (CGE) model. A CGE model is a system of equations that model the economy and the interdependencies between the sectors in the economy (Burfisher, 2021; Dixon & Jorgenson, 2012). A CGE model includes demand and supply equations for all goods and services and estimates how changes in the demand and supply of each good impact wages, employment, and household income (Kehoe et al., 2005). The Social Accounting Matrix (SAM), which is derived from the Input-Output (I-O) tables, provides the circular flow framework for economic activity for a specific year, including the value of production and the income from the sale of goods and services. The CGE model also includes demand and supply elasticities to measure responses to changes in prices and incomes. Regional CGE models can provide estimates of the impact of an event at the subnational level, however, the cost and complexity of these models often limits their adoption with regards to sub-state issues (Ghaith et al., 2021; Partridge & Rickman, 2010). A localized CGE model for Hampton Roads would require significant time, labor, and resources and would not be practical for the purposes of this study. If there was a desire to model the impact of sea level rise on Hampton Roads, the development and employment of a regional CGE would be an avenue worth exploring.

A second approach to the question of the impact of sea level rise is the use of regional I-O multipliers for regions as small as counties. In most systems, the core is based on the Bureau of Economic Analysis' (BEA) national I-O accounts. The national I-O accounts illustrate how goods and services produced by an industry are used by other industries and end users (Bureau of Economic Analysis, 2009). The BEA publishes the national I-O accounts and the Regional Input-Output Modeling System (RIMS II) which accounts for variations in regional supply conditions (Bureau of Economic Analysis, 2018). While a CGE model estimates dynamic responses among the sectors in the economy, regional I-O tables are static.

Assume that producers are grouped into n industries and that technology within an industry is homogenous but heterogeneous across industries. Production is assumed to be strictly linear, and purchase patterns are assumed to be fixed. Industries are assumed to be homogenous, and there are no supply constraints. Lastly, there are no regional feedback mechanisms and no time dimension in most (but not all) I-O models. Let each industry i produce gross output X_i. Industry i sells output X_i to other industries z_{ij} and to final users, Y_i. Industry production is assumed to be collectively exhaustive. Equation (1) defines the gross output of industry i is equal to:

$$\mathbf{X_i = z_{i1} + z_{i2} + \ldots + z_{in} + Y_i}$$

Given this definition of industry production, equation (2) defines the set of technical coefficients across the industries in the I-O model. The technical coefficients are used to create the national make and use tables, which, in turn, are used to create the domestic direct requirements, regional direct requirements, household use, and regional total requirement tables. From these requirement tables, we obtain the indirect and induced multipliers to estimate total economic impact.

$$a_{ij} = \frac{z_{ij}}{X_i}$$

We use IMPLAN to model the economic impacts associated with a hurricane making landfall in the Hampton Roads metropolitan area. IMPLAN is comparable to the BEA's RIMS II multipliers but provides added detail on the workforce impacts associated with changes in household spending (Gc et al., 2024; Kashian et al., 2021; Khalaf et al., 2022). However, we recognize that the IMPLAN impacts are static, that is, they fail to account for feedback effects of a change in direct expenditures or employment. IMPLAN uses a SAM to augment its estimates, however, IMPLAN Industry Schemes require a manual bridge to the NAICS industry codes. The REMI model, on the other hand, is a dynamic model and economic impact tool; however, financial considerations preclude its use for this study.

We recognize that uncertainty about future economic conditions and sea level rise may increase (or decrease) the economic impacts resulting from a natural disaster (Weitzman, 2011). Global mean temperatures continue to increase, making 2023 the hottest year on record with global temperature averages surpassing pre-industrial levels by approximately 1.5 degrees Celsius. Increasing temperatures are positively correlated with rising sea levels. If efforts to reduce greenhouse gas emissions are not successful, global average temperatures may rise faster than current projections, and, consequently, current projections of sea level rise would underestimate the rise in future sea levels and resultant flooding (Cazenave & Cozannet, 2014; Church & White, 2006; Frederikse et al., 2020; Minière et al., 2023). All else being equal, damages from a hurricane making landfall in the Hampton Roads metropolitan area are likely to increase as sea level rise occurs.

With these caveats in mind, we employ IMPLAN and the estimates of flood and wind damage by occupancy and to estimate the impact of a natural disaster on economic output, compensation, payrolls, and value added. We then aggregate the estimates of economic impact to obtain our final projections of the impact of in 2024 dollars. Lastly, we recognize that our analysis is limited in scope. Sea level rise is likely to exacerbate health and income inequities and reduce the scale of public services in conjunction with the projected declines in economic activity (Allaire, 2018). Sea level rise may also disrupt innovation and entrepreneurship, reducing economic efficiency, and creating a reinforcing cycle of economic decline (Zhao et al., 2022). We suggest that future efforts incorporate these (and other) potential spillovers on workforce resiliency.

Insurance Payments and Public Sector Responses

The physical damage from a hurricane is only part of the total impact on the economy. A major storm striking the region would not only damage structures and displace residents, it also would also impact economic activity (Melecky & Raddatz, 2015). While direct damages (property damage to homes, contents, and cars) may be the most visible, households face a myriad of other expenses in the aftermath of a significant natural disaster. While insured households may use insurance to cover direct and additional (evacuation, cleanup, loss of income) costs, uninsured households may find themselves using personal networks in an attempt to reduce financial losses (You & Kousky, 2024). There is evidence to suggest that after Hurricane Katrina struck New Orleans in 2005, there were only modest and temporary increases in debt delinquency rates among flooded residents (Gallagher & Hartley, 2017). When disaster assistance is available following a tornado, credit card debt and bill delinquency rates decline, and consumption, establishments, and employment appear to increase (Gallagher et al., 2023).

The transfer of damages from a natural disaster to insurers facilitates post-disaster recovery efforts. The voluntary purchase of insurance, including flood insurance, however, is low, with multiple studies estimating that approximately 50% of homeowners in 100-year floodplains participate in the National Flood Insurance Program (NFIP) (Kousky, 2017; Wagner, 2022). While sufficiently insured disasters have a negligible impact on output, uninsured losses drive subsequent economic losses (von Peter et al., 2012). After Hurricane Harvey struck Houston in 2017, homeowners in the 75th percentile of flood insurance claims observed no loss in housing value and generated positive spillovers on the prices of nearby uninsured homes (Box-Couillard & Xu, 2024). After Hurricane Harvey, credit-constrained households who were outside the floodplain in Houston and were flooded experienced a 20% increase in bankruptcies and a 13% increase in the share of debt in severe delinquency relative to non-flooded areas (Billings et al., 2022). While flood insurance uptake rates increase in the aftermath of a hurricane, the increase is short-lived, dying out within 3 years of the storm (Kousky, 2017). While risk perceptions appear to be influenced by the salience of the risk, the increases in subjective risk assessment appear to diminish over time (Siegrist & Gutscher, 2006). A 2023 survey by the Insurance Information Institute found that 22% of homeowners reported that they were at risk for flooding and that 78% of these homeowners purchased flood insurance. Within the 78% of homeowners who purchased flood insurance, 35% purchased private insurance while 43% purchased NFIP insurance. In other words, 7.7% of all homeowners were covered by a private flood insurance policy and 9.5% of homeowners were covered by a NFIP policy.[1]

Table 4 provides NFIP uptake rates and median premiums for the localities in the study area for 2022. Poquoson has the highest uptake rate with 66.8% of occupied residences having an active NFIP policy at the end of 2022. Hampton (17.0%), Virginia Beach (12.5%), Norfolk (12.4%), and York County (11.4%) are the other localities with uptake rates above 10% of occupied residences. Increasing awareness of flood risk would likely lead to higher uptake rates for flood insurance throughout the region.

[1] https://www.iii.org/sites/default/files/docs/pdf/2023_q2_ho_perception_of_weather_risks.pdf

Table 4.
National Flood Insurance Program Coverage
Hampton Roads, 2022

Locality	NFIP Median Premium	NFIP Uptake Rate
Chesapeake	$673	9.1%
Franklin	$2,784	0.9%
Gloucester	$760	9.4%
Hampton	$711	17.0%
Isle of Wight	$596	2.4%
James City	$654	3.1%
Newport News	$607	2.4%
Norfolk	$689	12.4%
Poquoson	$835	66.8%
Portsmouth	$654	9.9%
Southampton	$741	2.2%
Suffolk	$549	2.6%
Surry	$805	1.4%
Virginia Beach	$687	12.5%
Williamsburg	$568	0.9%
York	$748	11.4%

Source: U.S. Government Accountability Office report number GAO-23-105977, 2023.

To estimate the proportion of residences covered by private or NFIP flood insurance, we use the 2022 NFIP uptake rates by locality. We supplement the NFIP uptake rates with the survey data on private flood insurance uptake from the Insurance Information Institute. We assume that residences covered by flood insurance are sufficiently insured to offset any damages from the Florence-like hurricane. We assume that public and educational buildings are, in effect, fully insured from loss and that other non-residential buildings are covered at the same rate as residential buildings.

Table 5 presents total damages from wind and water as well as estimated uninsured damages from the Category 3 hurricane. An open question is how much aid would flow from the state and federal government to Hampton Roads in the aftermath of a hurricane. The Congressional Budget Office estimated that the combination of private insurance coverage for wind damage, federal flood insurance, and federal disaster aid would cover approximately 50% of residential losses and 40% of commercial losses from a significant storm event (Congressional Budget Office, 2019). The timing and coordination of federal relief would impact how damages impact economic activity over time. The Government Accountability Office noted that, in the aftermath of Hurricane Sandy in 2023, 19 federal agencies were appropriated funds for more than 60 federal programs in order to provide assistance (U. S. Government Accountability Office, 2015). Delays in financial assistance to households and businesses, as well as repairs to infrastructure, would delay recovery from the hurricane.

Higher-income households and businesses would likely recover faster from the natural disaster through a combination of insurance, aid, and the use of savings. Lower-income and lower-wealth households would likely face financial difficulties in recovering completely or, relative to higher-income households, would face slower recoveries (Fothergill & Peek, 2004; Peacock et al., 2014; Zhang & Peacock, 2009). Mapping flood risk to median household income at the census tract level would highlight those households with the highest vulnerabilities to a natural disaster.

Another question is how to distribute the damages to buildings with residential occupancy. We use the U.S. Census Bureau's 2022 American Community Survey to estimate the distribution of households by household income. We apportion the damages by the distribution of household income. An avenue of future research would be to map the Hazus results by census tract to gain greater fidelity on the distribution of damages by income groups across the region.

Table 5.
Expected Total and Uninsured Damages
Category 3 Hurricane Striking Hampton Roads with 3.6 Feet Tidal Offset

Occupancy Type	Total Damages (Thousands of Dollars) (3.6 Feet Tidal Offset)	Uncovered Damages (Thousands of Dollars) (3.6 Feet Tidal Offset)
Agriculture	$42,244	$42,244
Commercial	$2,336,131	$1,765,225
Educational	$847,039	$0
Government	$253,605	$0
Industrial	$810,915	$614,392
Religion	$331,330	$331,330
Residential	$11,005,946	$8,031,052
Totals	**$15,627,211**	**$10,784,244**

Source: HAZUS (2024) and authors' estimates. Numbers may not sum to totals due to rounding.

Economic Impacts

Table 6 presents the short-term estimated economic impacts in 2024 from uninsured losses from a Category 3 hurricane making landfall in Hampton Roads. Our first observation is that the direct damages from the hurricane will result in a short-term loss of approximately 20,000 jobs in the metropolitan area, with a direct reduction of regional GDP by approximately $1.4 billion. The indirect (supply chain) impacts are approximately 5,100 jobs and a reduction of regional GDP by approximately $509.8 million in 2024 dollars. The induced economic impacts are the most significant, reflecting the preponderance of damages to buildings with residential occupancy. Reductions in household incomes due to uninsured losses lower demand, which in turn, negatively impacts businesses and employment in the metropolitan area.

Table 6.
Estimated Short-Term Economic Impacts
Category 3 Hurricane Striking Hampton Roads with 3.6 Feet Tidal Offset

Impact	Employment	Labor Income	Value Added	Output
Direct	19,797	$1,279,919,166	$1,415,713,231	$2,715,170,000
Indirect	5,146	$293,288,982	$509,807,018	$1,003,927,211
Induced	51,635	$2,487,993,466	$5,205,232,803	$8,900,187,302
Total	**76,579**	**$4,061,201,615**	**$7,130,753,053**	**$12,619,284,513**

Source: IMPLAN (2024) and authors' estimates. Numbers may not sum due to rounding.

Table 7 presents the impact of the hurricane on nonfarm payrolls (jobs). The largest impact on employment is in the Other Services (except Public Administration) sector. This sector consists of establishments primarily engaged in activities such as equipment and machinery repair, dry cleaning and laundry services, personal care and death services, pet care services, and dating services, among others. In other words, this sector contains jobs that provide services to residences which bear the preponderance of costs associated with a natural disaster. We estimate a short-term reduction of more than 23,000 jobs in the metropolitan area in the Other Services sector.

We project more than 9,400 estimated job losses in the Retail Trade and Health Care and an additional 9,200 job losses in the Social Assistance sector. These job losses are (as with Other Services) closely tied to the consumption of personal services. The financial losses sustained by households negatively impact the consumption of these services which, in turn, induce job losses in the short-term.

The Accommodation and Food Services sector is estimated to observe a decline of more than 7,000 jobs. These job losses are related to the losses incurred by households in Hampton Roads and a decline in tourism following the natural disaster. Given the damages to buildings and infrastructure, it should not be surprising that tourism to Hampton Roads would decline in the immediate aftermath of a hurricane making landfall in the region.

Table 7.
Estimated Short-Term Employment Impacts
Category 3 Hurricane Striking Hampton Roads with 3.6 Feet Tidal Offset

Industry	Direct Impact	Indirect Impact	Induced Impact	Total Impact
Other Services (except Public Administration)	17,495	154	5,753	23,402
Retail Trade	0	103	9,327	9,431
Health Care and Social Assistance	0	1	9,221	9,222
Accommodation and Food Services	0	243	6,774	7,017
Real Estate and Rental and Leasing	0	829	3,066	3,896
Transportation and Warehousing	0	507	3,168	3,675
Administrative and Support and Waste Management and Remediation Services	0	876	2,540	3,416
Finance and Insurance	0	476	2,894	3,370
Professional, Scientific, and Technical Services	0	700	1,810	2,509
Manufacturing	2,117	69	264	2,450
Arts, Entertainment, and Recreation	0	67	1,697	1,764
Wholesale Trade	0	432	1,101	1,533
Educational Services	0	24	1,429	1,453
Management of Companies and Enterprises	0	420	657	1,077
Information	0	75	653	728
Government Enterprises	0	87	624	711
Construction	0	61	377	439
Agriculture, Forestry, Fishing and Hunting	185	3	102	290
Utilities	0	18	172	190
Mining, Quarrying, and Oil and Gas Extraction	0	1	7	8
Total	**19,798**	**5,147**	**51,635**	**76,580**

Source: IMPLAN (2024) and authors' estimates.

The economic impacts in Table 6 and 7 illustrate how increasing flood insurance uptake rates in Hampton Roads would have benefits far greater that just to homeowners. Increasing flood insurance uptake rates would have a preventive effect on household incomes, that is, reducing the financial damages associated with water damages from a hurricane making landfall in Hampton Roads. These financial damages reduce household consumption which, in turn, reduces the demand for goods and services in the regional economy. Given the relatively low uptake rates for NFIP insurance in the region, an effective policy response would be to increase awareness of these programs and, in the case of lower income households, to provide financial assistance in obtaining flood insurance.

Policy Recommendations and Avenues for Future Research

In this paper, we have explored the potential economic impacts associated with a major hurricane making landfall in Hampton Roads. The study builds on previous work from 2019 by estimating the potential workforce impacts of the natural disaster. We estimate the direct damages from a Florence-like Category 3 hurricane with a 3.6 feet tidal offset are estimated at $15.6 billion, equivalent to 10% of the 2022 regional GDP. If we apply existing flood insurance rates to these projected damages, we estimate that the total economic impact would exceed $12 billion with a short-term loss of more than 76,000 jobs.

We note that previous research highlights significant heterogeneity in approaches and results regarding the economic impact of sea level rise and recurrent flooding. We find that most economic damages from a hurricane would result from reductions in household income. Given the significant economic impacts projected from future sea level rise and major storm events, it is crucial for policymakers to adopt a comprehensive approach to enhance the region's resiliency. A first step would be to improve flood insurance uptake rates throughout the region as previous research has shown that insured residences are less likely to incur significant financial damages from a natural disaster.

We recommend that Hampton Roads prioritize investments in resilient infrastructure, including flood defenses, stormwater management systems, and sustainable urban planning. This includes upgrading existing structures and building new ones that can withstand extreme weather events. We encourage economic diversification to reduce dependency on vulnerable industries. This can be achieved through incentives for businesses in less flood-prone sectors and the promotion of innovation and technology-driven enterprises. We also recommend that localities in Hampton Roads develop programs to support workforce retraining and education, focusing on skills needed for resilient and emerging industries. Local cities and counties should examine emergency response plans to determine their capacity to support displaced workers and communities during recovery periods. Reducing the induced economic impacts from a hurricane making landfall in the region is key to building workforce resiliency to prevent workforce losses in the immediate aftermath of a hurricane making landfall in the region.

There are a number of avenues for future research to consider. Examining flood insurance uptake rates at the highest level of fidelity with respect to flood risk is important to improve understanding the risk associated with a natural disaster. Incorporating household income and other measures of socio-economic resiliency will provide decision makers with information on how to target resiliency and adaptation efforts to return the highest yield. Examining how proposed mitigation efforts would reduce household losses and improve workforce resiliency is also an avenue worth pursuing in the future.

To estimate the net present value of the losses associated with the proposed projects, we employ damage estimates from HAZUS as generated by Virginia Beach Public Works Stormwater Engineering Center and Dewberry. As noted by the United States Geological Service, the federal government employs annual exceedance probabilities (AEPs). The most used definition is a '1 in 100-year flood.' This refers to a flood level that has a one in one hundred, or 1%, chance in being equaled or exceeded each year. Following standard practice, this is noted as a 1% AEP.

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