Private versus Public Flood Insurance: Differences in Premiums and Uptake Observed in Two Coastal Housing Markets Using Survey Data

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ABSTRACT

Using a natural experiment created by the 1982 Coastal Barrier Resources Act (CBRA), we measure the extent to which insurance premiums vary between private and publicly backed flood insurance policies. The CBRA resulted in homeowners living in neighboring housing markets in which some have access to the federally backed National Flood Insurance Program (NFIP) and others do not. Flood risks and other features of the neighborhoods are otherwise indistinguishable. Those without access to publicly backed insurance must purchase private insurance if they desire coverage. We compare insurance premiums and uptake in the two markets and find that premiums for private coverage are significantly higher than public rates (after controlling for other factors in a reduced-form regression), implying a subsidy by NFIP. We also find a much lower uptake of insurance in the areas without federally backed insurance. Our results are based on a mail survey of residents in two US coastal communities with a 50% response rate: North Bethany Beach, Delaware, and North Topsail Beach, North Carolina. We also present results related to perceptions of flood hazards, of being under- or overinsured, and measures taken to mitigate flood damage.

Key words: Economics, flood, insurance, NFIP, premiums, subsidy.
JEL codes: G22, H84, Q54, R38.

INTRODUCTION

The National Flood Insurance Program (NFIP) backs insurance for over 5 million households representing over $1.3 trillion of coverage, protecting homeowners in flood hazard areas along ocean coasts, the Great Lakes, and riverine regions of the United States. The NFIP has long been at the center of a debate on the adequacy and necessity of public provision of natural catastrophe insurance. Since Hurricane Katrina in 2005, the NFIP has been operating at a financial loss. Following the 2017 storm season—which included hurricanes Maria, Irma, and Harvey—the NFIP was left holding a debt of nearly $21 billion to the US Treasury (Congressional Research Service 2021a). With storm events and flooding projected to increase in frequency and intensity, the financial difficulties facing the NFIP are likely to increase (IPCC 2021; Dinan, Beider, and Wylie 2019; Adler et al. 2019).

Considering the program's ongoing financial problems and aging risk modeling methods, the Federal Emergency Management Agency (FEMA) enacted a reform to the program referred to

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as Risk Rating 2.0. Taking effect October 2021, Risk Rating 2.0 uses new flood modeling techniques to assess flood risk (Congressional Research Service 2021b). The new system is also intended to eliminate subsidized rates from the policy base—a process begun in 2012 with the Biggert-Waters Flood Insurance Reform Act. It is estimated that premiums will increase for 77% of homeowners currently with policies (Congressional Research Service 2021b). The pricing adjustment is capped at a maximum of 18% increase in premiums per year. While the need to address the NFIP's financial solvency issue is widely accepted, affordability concerns from increased premiums as well as the actuarial soundness of the program remain ongoing issues for Risk Rating 2.0 (Government Accountability Office 2023).

Prior to implementation of new Risk Rating 2.0 pricings, NFIP insurance has been "based on consideration of the risk involved and accepted actuarial principles," so the provided rate should represent the true flood risk to the property (Congressional Research Service 2021a; National Flood Insurance Act 1968). To arrive at this rate, FEMA follows a formula of which the key components include the property's risk zone as indicated by its Flood Insurance Rate Map (FIRM), the occupancy type, the elevation of the property in relation to the base flood elevation, and other specific determinants of risk. However, multiple government reports and academic studies have called into question the validity of the methods used by FEMA to assess risk and to arrive at insurance rates (Government Accountability Office 2020; National Research Council 2015; Office of Inspector General 2020; Smith and Whitmore 2019). The bulk of this criticism lies in the argument that FIRMs are not sufficiently granular and are updated too infrequently, and that risk from fluvial and pluvial flood events are not accurately captured in current models (Congressional Budget Office 2017). Studies have further shown these policies to be generally held by wealthy homeowners, with a large percentage covering secondary and vacation homes, further calling into question the financial justification behind the publicly funded program (Kahn and Smith 2017; McGuire and Goodman 2015; Holladay and Schwartz 2010).

Whether FEMA's models accurately depict a given property's flood risk, however, is a somewhat different question than the actuarial soundness of the program. While definitions of "actuarial soundness" can vary, it is generally given to mean that the program is run such that premiums are able to meet projected liabilities (Cleary et al. 2020). Such a definition is complicated by the prevalence of explicitly subsidized properties contributing to the policy base, as well as by the nature of flood risk and the mandates of the NFIP to both provide flood insurance and promote better floodplain management.

When the NFIP was formalized in 1968, it was done so with the acknowledgment that "many factors have made it uneconomic for the private insurance industry alone to make flood insurance available to those in need of such protection on reasonable terms and conditions" (Congressional Research Service 2021a). The uninsurability argument usually points to the difficulty of accurately quantifying flood risk, adverse selection resulting in risk not being spread over a wide enough base, losses tending to impact a wide geographic area simultaneously, and the potential for catastrophic losses of unpredictable and extreme magnitudes (Overman 1957; Michel-Kerjan 2010). Only in recent decades has this argument been challenged by increasingly sophisticated models deployed by private insurance companies (Michel-Kerjan, Czajkowski, and Kunreuther 2015; Torres-Lugo 2021).

Private flood insurance as an industry has been growing in status and scope over the past two decades. Still, its overall share of the US flood insurance market remains small (Kousky and Kunreuther 2018). Regulations have made expansion difficult for private companies in some states

but not others. This has resulted in a concentration of policies in more lenient states. Puerto Rico and Florida, for example, have a large market penetration. To circumvent the difficulties of natural disaster insurance—unpredictable and catastrophic risk in concentrated geographic areas—the market has been dominated by global reinsurers able to absorb these financial challenges (Kousky and Kunreuther 2018). While the NFIP, by design, provides insurance to any residential property, private insurers can be more selective. They also can provide greater flexibility in policy coverage, for example, by offering coverage beyond NFIP's limits. Further, their rates are not determined by FEMA's flood mapping, but rather by their own private catastrophe models and financial analyses.

This can result in a wide discrepancy between NFIP rates and those determined through alternative means. For instance, Michel-Kerjan, Czajkowski, and Kunreuther (2015) find NFIP premiums ranging from 15 times greater than to three times less than the "pure premium" estimated through simulated models. In an analysis of how privatization of flood insurance may be developed, Born and Klein (2019) argue that the potential welfare benefits of privatization of flood insurance—primarily through the lowering of regulatory barriers and incentivization of private companies to offer flood insurance—would outweigh the concerns such a process would entail. A more commonly advocated approach to improve the NFIP is by means of a hybrid public-private strategy to flood insurance provision, in which competition through private markets and improved risk modeling enables more efficient provision and geographically precise policies, while regulators help to ensure equity of implementation and consumer protection (Born and Klein 2019; Kousky and Kunreuther 2018; Altun and Güldiken 2019). As noted, despite the growing recognition of the potential for private flood insurance providers, they currently play a minor role in the flood insurance market, acting primarily as supplemental insurers offering greater policy-term flexibility.

Despite difficulties in analyzing flood insurance because of limited premium variation, rare updates to premium schedules and flood maps, mandatory purchase requirements, low market penetration, and limited availability of private flood insurance, a robust literature has focused on the uptake of flood insurance and factors influencing demand. This literature has generally found higher rates of uptake and coverage in areas with greater hazards, higher levels of education, higher home values, longer lengths of residency, and higher expectation of future damage (Kriesel and Landry 2004; Michel-Kerjan and Kousky 2010; Landry and Jahan-Parvar 2011; Kousky 2011; Petrolia, Landry, and Coble 2012; Brody et al. 2017). Estimates of demand have been found to remain relatively inelastic and stable over time, increasing after a flood event and then fading in subsequent years, albeit with the market characterized by its heterogeneity and potential adverse selection of policyholders (Bin and Landry 2013; Gallagher 2013; Atreya, Ferreira, and Michel-Kerjan 2015; Ahmadiani, Ferreira, and Landry 2019; Bradt, Kousky, and Wing 2021). Meanwhile, studies have also found demand for flood insurance to be influenced by homeowners' belief in climate change (Ratnadiwakara and Venugopal 2019), expected future storm damage (Landry and Turner 2020), as well as the expectation that the government will provide post-disaster aid (Landry, Turner, and Petrolia 2021; Davlasheridze and Miao 2019; Kousky, Michel-Kerjan, and Raschky 2018). In a study perhaps closest to ours in its approach, Hennighausen et al. (2023) studied the impact of reforms to the NFIP in 2012/14 on flood insurance prices and other aspects of the market. These reforms moved the law in the direction of lowering subsidies. Using a difference-in-difference analysis with cross-sectional time series data, they find, as expected, an increase in insurance prices due to the change in policy.

Whether private insurance can represent a viable alternative to the NFIP, whether the NFIP is offering flood insurance at actuarially sound rates, and what implications this market has for the mitigation of flood risk for coastal communities are all issues in need of more research, particularly given the changing regulatory environment facing homeowners. This paper attempts to shed some light on these questions and inform the current debate centering on NFIP reform, the uncertain role of the private market in flood insurance, the larger questions of the future of coastal communities in a changing climate, and the extent to which federal policies may be subsidizing flood insurance.

STUDY DESIGN, STUDY SITES, AND SURVEY IMPLEMENTATION

STUDY DESIGN

We use the 1982 Coastal Barrier Resources Act (CBRA) as a natural experiment. The CBRA was passed with the intention of discouraging development on undeveloped barrier islands by limiting federal funding to selected areas on the coast. These became known as CBRA zones (pronounced "cobra zones"). Although the 1982 act did not explicitly define "undeveloped," the definitions and delineation criteria that guided the Fish and Wildlife Service's initial mapping (and later codified by the Coastal Barrier Resources Reauthorization Act of 2000) stipulated that to be considered developed, a coastal barrier area must have more than one structure per five acres of land or have a full complement of infrastructure on the ground before designation, to include a road, wastewater disposal system, electrical system, and fresh water supply (August 16, 1982, in the *Federal Register*, Vol. 47, No. 158). Properties in CBRA zones were precluded from federal funds to support infrastructure, federal flood insurance, and building loans backed by the Federal Deposit Insurance Corporation. CBRA's current total acreage stands at 1.3 million, after being modified and expanded in 1990. CBRA zones exist in 23 coastal states in the US, including states on the Atlantic, Pacific, Gulf, and Great Lakes coastlines.

The Government Accountability Office (2007) reported that 84% of all CBRA zones remain undeveloped, 13% are minimally developed (fewer than 20 additional structures since designation), and 3% are significantly developed (defined as having 100 or more additional structures). Again, the act does not prohibit development, it only withholds funding for public infrastructure and does not provide federally backed insurance (NFIP). By this accounting, the CBRA appears to have achieved its purpose, although we do not know whether development would have occurred in these areas without CBRA designation. Certain areas where "significant development" has occurred within CBRA zones sets up conditions for our natural experiment. There are a small number of communities along the coast where neighborhoods with CBRA zones and non-CBRA zones exist side by side and do so because of peculiarities of timing and how the zones were designated. The structures, roads, beaches, and the like in these communities are essentially identical, and the flood risks are the same. For practical purposes, the zones are indistinguishable but for one key feature: eligibility for federal flood insurance and other federal assistance.

With this natural experiment as a backdrop, we compare flood insurance in these adjacent neighborhoods—one having access only to private insurance and the other having publicly backed insurance. Our main interest is the wedge between public and private insurance premiums. If private premiums are greater than public premiums and we assume that private insurance is actuarially sound owing to market forces, then the difference between the public (NFIP) and private premium for the same level of coverage is a shadow value for the federal subsidy.

Treating the private-public rate difference as a subsidy is an imperfect measure. Private insurers will include a "loading factor" to cover transactions costs, operating costs, and profit. Also, the structure of the private insurance market will affect the degree to which the premiums are set at competitive rates. For these reasons, the private-public difference can be thought of as "how rates would change if the NFIP were to vanish," which may or may not be a change that reflects a move toward an efficient, competitive private market. Having said that, the private flood insurance market is composed of approximately 30 firms offering private flood insurance in the US, with Assurant, AIG, Liberty Mutual, and Chubb being the top four in the residential market (Kousky and Kunreuther 2018). Lloyds is a major insurer in the markets we consider. So, competitive pressure is no doubt in play in the markets we are studying.

In an analysis with similarities to ours, Druckenmiller et al. (2023) also use the CBRA as a natural experiment. Using machine learning and matching techniques to mimic the formation of CBRA zones, they identify non-CBRA areas to serve as "controls" against the "treated" CBRA zones in 18 coastal states. Then using data merged from several sources, they study the effects of a CBRA designation on rate of development, land values, property tax revenues, and demographics. Their analysis provides a convincing case that the CBRA has indeed limited development, with some effects spilling over on neighboring communities as well. Unlike ours, their attention is less directed toward comparisons of insurance in the two areas. Still, it provides a nice complement and reinforces our approach.

STUDY SITES

We use two coastal communities in the analysis: North Bethany Beach, Delaware, and North Topsail Beach, North Carolina (see figure 1). Both communities are examples of populated areas of comingled CBRA and non-CBRA zones on barrier islands. The communities are virtually indistinguishable in terms of natural, structural, and neighborhood features, and mostly importantly flood risks. The properties have good access to sandy beaches for relaxation and recreation

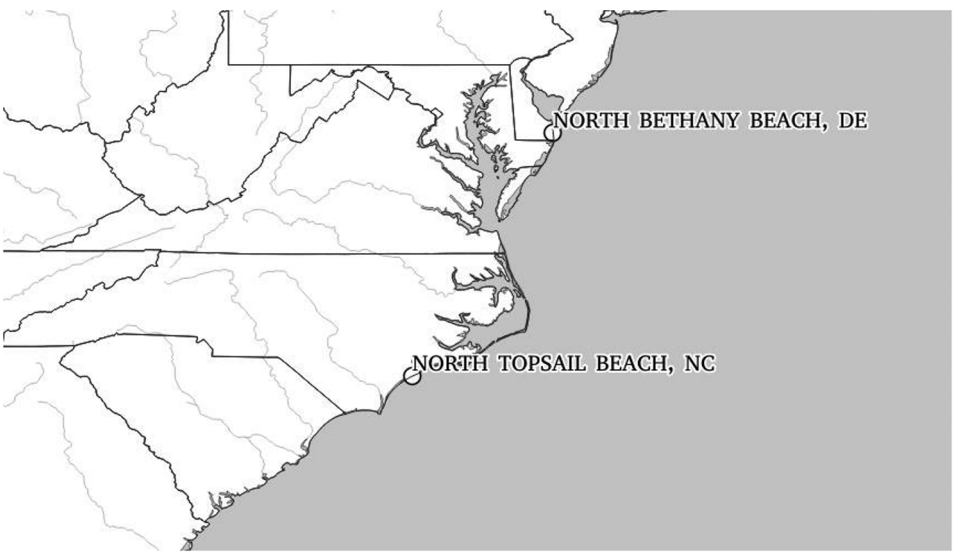

Figure 1. North Bethany Beach, DE, and North Topsail Beach, NC

and have an orientation toward vacation and retirement. The CBRA versus non-CBRA designation in both cases is the result of mapping errors and the timing of classification.

At the time of the CBRA mapping in the 1980s there were no structures in either community, but because of existing on-the-ground infrastructure and development plans in place both were candidates for exclusion from CBRA designation. For reasons not completely understood, some were and some were not designated as CBRA. Some refer to this situation as a "mapping error." Others have noted that simple timing (months of separation between mapping) may have led to the discrepancy. In any case, the disadvantages of having a CBRA designation have led to attempts by owners in the current CBRA zones in both communities to remove their designation. The attempts have been mostly unsuccessful. These include the 2017 S. 1745 and 2023 H.R. 2437 in North Topsail Beach's CBRA and 2018 H.R. 4880 in North Bethany Beach. A smaller segment was removed in Delaware from CBRA designation with the 2018 Strengthening Coastal Communities Act.

North Bethany is about 3 miles long and is located north of the town of Bethany, Delaware, and south of the Indian River Inlet. It is composed of several unincorporated communities of single-family homes and a few clusters of townhouses. Most of North Bethany is east of Route 1 (referred to as the Coastal Highway). It is an affluent community, with many second homeowners from nearby metropolitan areas such as Washington, DC, Philadelphia, and Baltimore. North Topsail is 11 miles long and is located on Topsail Island. It is less affluent than North Bethany and has more primary residents. Most of the homes are single-family residences. Further, the coast of North Carolina is more prone to coastal storms and flooding, as indicated by a recorded 21 major disaster declarations by FEMA concerning hurricanes, severe storms, and floods over the period in Onslow County from 1970 to 2019, compared with 11 for Sussex County in Delaware.

Figure 2 shows how the CBRA and non-CBRA zones are commingled. The black (CBRA) and white (non-CBRA) dots represent properties used in the analysis, with the CBRA zones shown as hashed areas. As noted above, both areas have a history of CBRA zone property owners making a case to be included in the non-CBRA zone and hence be eligible for NFIP. Among other legal details, the owners have argued that the initial mapping was in error, that flood risks are the same, and that development was already under way at the time of the designation. While there have been minor adjustments made, which added some and subtracted others, the study area has mostly remained unchanged with respect to which properties are in and out of the CBRA zone. Property owners continue to pursue other channels to remove the CBRA designation.

Given the similarities naturally (elevation, flood risks, erosion rates, proximity to the coast), structurally (housing units are nearly indistinguishable), and by neighborhood characteristics, we believe the natural experiment is a good one but admit even with the upcoming analysis controlling for differences that there is still the possibility of undiscovered differences.

SURVEY IMPLEMENTATION

The data for our analysis come from a mail survey of property owners at the two sites. The surveys and the accompanying cover letters (shown in the online appendix) are identical for the two areas with a few minor differences mentioned below. After defining the areas to be sampled, ownership of properties was determined using property records. All households residing in what is commonly defined as North Bethany were sampled ($n = 1{,}140$). Of these, 19% were in a CBRA zone. A random sample of 1,200 was drawn for North Topsail (half in and half outside the CBRA zone). The survey was done in late 2020 and early 2021.

Figure 2. Observations Indicating Non-NFIP Units (black) and NFIP Units (white) for North Bethany (left) and North Topsail (right). CBRA zones are depicted in hashed areas. Note that Topsail's CBRA zone contains two communities with NFIP units—a regulatory anomaly but nevertheless a true reflection of those communities' status.

Owners were then mailed a three-page survey of 22 questions along with a cover letter describing the purpose of the survey. We used three mailings to residents in North Bethany and two in North Topsail, owing to the communities' differing initial population sizes and acceptable levels of nonresponse. Each mailing included an incentive payment of $5 or $10. We had a 55% response rate in North Bethany and a 49% response rate in North Topsail.

The survey had three parts. First, we asked respondents to report property details including age, size, value, distance from the beach, and so on. Second, we asked about their flood insurance policy, such as whether they had one and what the premium and coverage were. Respondents had the option of filling in the information on the survey or mailing us a copy of their policy, which 11% and 15% of North Topsail and North Bethany respondents with flood insurance did, respectively. Finally, we asked several questions concerning flood risk perceptions and about any mitigation they had taken against flood risks. CBRA and non-CBRA properties were determined from US Fish and Wildlife Service CBRA maps and physical addresses geocoded using Google Maps API. The same set of questions was sent to CBRA and non-CBRA homeowners.

DESCRIPTIVE STATISTICS: HOUSING, INSURANCE, AND RISK PERCEPTION

HOUSING MARKET

Table 1 is a profile of the houses in our two samples. We exclude condominiums since their flood insurance policies are usually embedded in their condominium contract, are shared across a group of homeowners, and are often unknown (the coverage and premium levels) to respondents. This gives us a sample of 542 single-family homes in North Bethany of which 25% are in a CBRA zone and a sample of 531 single-family homes in North Topsail of which 57% are in a CBRA.

Table 1. Descriptive Statistics of Single-Family Houses

	North Bethany Beach		North Topsail Beach	
Variable	Non-CBRA	CBRA	Non-CBRA	CBRA
Year built				
Mean	1986**	1994**	1992**	1997**
Range	1950–2019	1979–2017	1950–2017	1965–2018
Year purchased				
Mean	1999	2001	2005	2007
Range	1953–2019	1977–2019	1949–2019	1948–2019
Market value (000 $)				
Median	1,500	1,700	400	500
Mean	1,797	2,147	426	564
Range	100–11,000	850–6,000	75–1,800	50–3,800
Number of bedrooms				
Mean	4.81**	5.35**	3.44**	4.05**
Range	3–13	4–10	2–9	1–16
Street row (from beach)				
Mean	4.12	4.19	NA	NA
Range	1–10	1–10		
Oceanfront	80 (20%)	24 (18%)	66 (29%)**	160 (53%)**
House elevated	352 (87%)**	127 (93%)**	213 (93%)	287 (95%)
Primary residence	30 (7%)**	13 (10%)**	52 (23%)**	38 (13%)**
Have mortgage	NA	NA	108 (47%)	106 (35%)
Have flood insurance	77%**	40%**	71%**	41%**
Built pre-FIRM	101 (25%)**	1 (1%)**	95 (41.3%)**	105 (35%)**
Sample size	406	136	230	301

Note: ** CBRA and non-CBRA pairs that are statistically significantly different at the 95% level. The tests were done over the percentages (not absolute values) for the last five variables in the table.

The market value of the homes in North Bethany ranges from $100,000 to $11 million (mean = $1.9 million). They have from 3 to 13 bedrooms (mean = 5) and they are located 1 to 10 rows from the beach (mean = 4.1). About 20% are oceanfront properties. Nearly all are elevated. The houses were built from 1950 to 2017. Only 8% of the homes are reported as being primary residences. As shown, the homes in the CBRA zone are newer (8 years younger on average) owing to the timing of the CBRA designation, slightly larger (11% larger on average), and higher priced (13% higher on average).

The homes in North Topsail have a lower market value, ranging from $50,000 to $3.8 million (mean = $505,000). They are smaller homes (by about one bedroom) but newer (by 8 years), and more are located on the oceanfront (42%). Like in North Bethany, the homes in the North Topsail Beach CBRA zones are newer, larger, and of a higher market value (by 25%) than their non-CBRA counterparts. Unlike North Bethany, more homes have oceanfront in the CBRA (53%) versus non-CBRA (29%) zones.

Table 1 also reports the number of houses that were built pre-FIRM. Pre-FIRM houses qualify explicitly for federal subsidies and so are important to control for in our analysis. Pre-FIRM houses that undergo renovation or rebuilding lose their eligibility for subsidy.

INSURANCE

Respondents were asked to report details on their flood insurance including whether they own an insurance policy and, if so, the amount of coverage, premium paid, and deductible applied.

Table 2. Descriptive Statistics of Flood Insurance Policies

	North Bethany Beach		North Topsail Beach	
Variable	Non-CBRA	CBRA	Non-CBRA	CBRA
Premium ($)				
Median	997	3,881	1,006	8,106
Mean	2,135	4,883	2,471	7,404
Range	300–26,092	696–17,200	297–15,255	333–15,925
Premium (per $100 building coverage) ($)				
Median	0.38	1.33	0.60	3.24
Mean	0.76	1.50	1.20	2.88
Range	0.05–6.00	0.27–3.96	0.12–6.10	0.13–6.37
Building coverage (000 $)				
Median	250	250	250	250
Mean	300.70	381.90	226.90	287.30
Range	22–2,778.30	150–1,872.70	17.50–1,000	65–1,350
Building deductible ($)				
Median	1,250	7,500	2,000	3,200
Mean	2,839	11,054	3,517	4,323
Range	0–20,000	500–50,000	500–25,000	500–25,000
Sample size	266	50	142	92

Individuals were also asked whether they held a second flood insurance policy, whether their rates had increased during the past five years, and whether they had filed a flood insurance claim.[1]

There is a statistically significant difference (95% level) in the share of homeowners with flood insurance in the CBRA versus non-CBRA zones. In the non-CBRA zones in North Bethany and in North Topsail, 77% and 71% of the owners reported having flood insurance. In the CBRA zones, the same numbers are 40% and 41%. Given that both communities are in FEMA's Special Flood Hazard Area, any federally regulated lender must require homeowners to purchase flood insurance as a condition of their loan. Home buyers without a mortgage or not using a federally regulated lender may forego flood insurance.

Of those respondents who purchased flood insurance in North Bethany, 316 provided complete data on the details of their insurance. In North Topsail 240 provided complete data. Reporting on a flood insurance policy called for retrieving the policy for most respondents, which no doubt led to item nonresponse. Still, the sample size is adequate, and we have no reason to believe nonresponse along these lines would introduce bias. Table 2 shows relevant data on insurance in both communities: premiums, coverage, and deductibles. Figure 3 shows the distribution of annual flood insurance premiums. As expected, the premiums in the CBRA zones are higher than in the non-CBRA zones. This is true in absolute and per-$100-coverage terms. In North Bethany, 52% of the non-CBRA premiums are less than $1,000, while only 6% of the CBRA premiums are less than $1,000. The median premium is $997 in the non-CBRA versus $3,881 in the CBRA—nearly a factor of 4. The spread is smaller at the mean: $2,135 versus $4,883, or about a factor of 2. In both zones, the mean is larger than the median. This arises from a small share

1. In North Topsail, 10 respondents indicated they held a second supplementary flood insurance policy out of 238 returned surveys with flood policy information provided (9 in CBRA, 1 in non-CBRA). In North Bethany, 37 out of 315 respondents providing policy information held second policies (32 of which were located in non-CBRA zones).

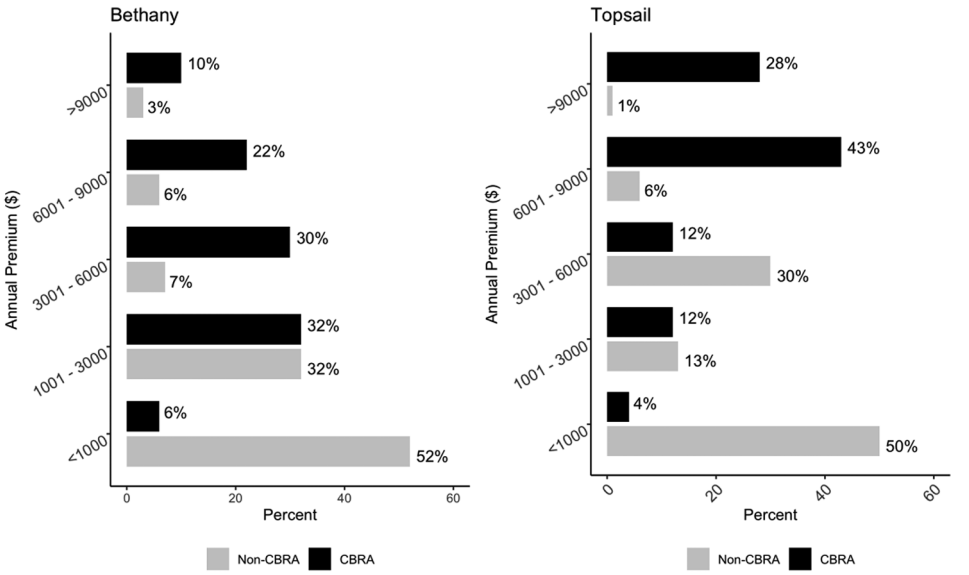

Figure 3. Flood Insurance Premiums by Non-CBRA and CBRA Zones

of households seeking higher coverage (and hence higher premium) policies—some with premiums over $17,000 per year. In terms of premium per-$100-coverage, the non-CBRA zone rates at the median and mean are $0.38 and $0.76. In the CBRA zone, the median and mean are $1.33 and $1.50. Here the factors (CBRA to non-CBRA) are 3.5 and 2, close to what we see using absolute terms for the premiums. In the non-CBRA zone, coverage beyond $250,000 (the federally mandated limit) is through private insurance.

North Topsail premiums are higher than in North Bethany and the spread between non-CBRA and CBRA premiums is larger. Like North Bethany, 50% of the premiums in the North Topsail non-CBRA zone are below $1,000, while only 4% are below $1,000 in the CBRA zone. In the non-CBRA zone, the median is $1,006 and in the CBRA zone it is $8,106. The respective means are $2,471 and $7,404. Here, the differences are a factor of 8 at the median and 3 at the mean. We see the same skewing to the right in North Topsail—a handful of households with very high coverage levels. In terms of premium per-$100-coverage, the non-CBRA zone median and mean rates are $0.60 and $1.20, and in the CBRA zone are $3.24 and $2.88. Here the factors are 5.5 and 2.5.

Figure 4 shows scatterplots of premium by coverage and premium by deductible in both study areas. Higher premiums are evident in the CBRA zones in all plots. The correlations with premiums are also evident in both plots but are not as pronounced as we had expected given the presumed importance of coverage amount and level of deductible in writing an insurance policy as well as the similarity of the properties in terms of risk profiles and structural makeup. See, for example, the variance in premiums at $250,000 coverage and at $5,000 deductible, what are sometimes referred to as the "market standards." The range in premium level is quite wide in both cases for the same level of coverage and deductible. It is also interesting to note that households are more likely to purchase less than the standard $250,000 in North Topsail where the cost of insurance is significantly higher, and value of the homes is lower than in North Bethany. The

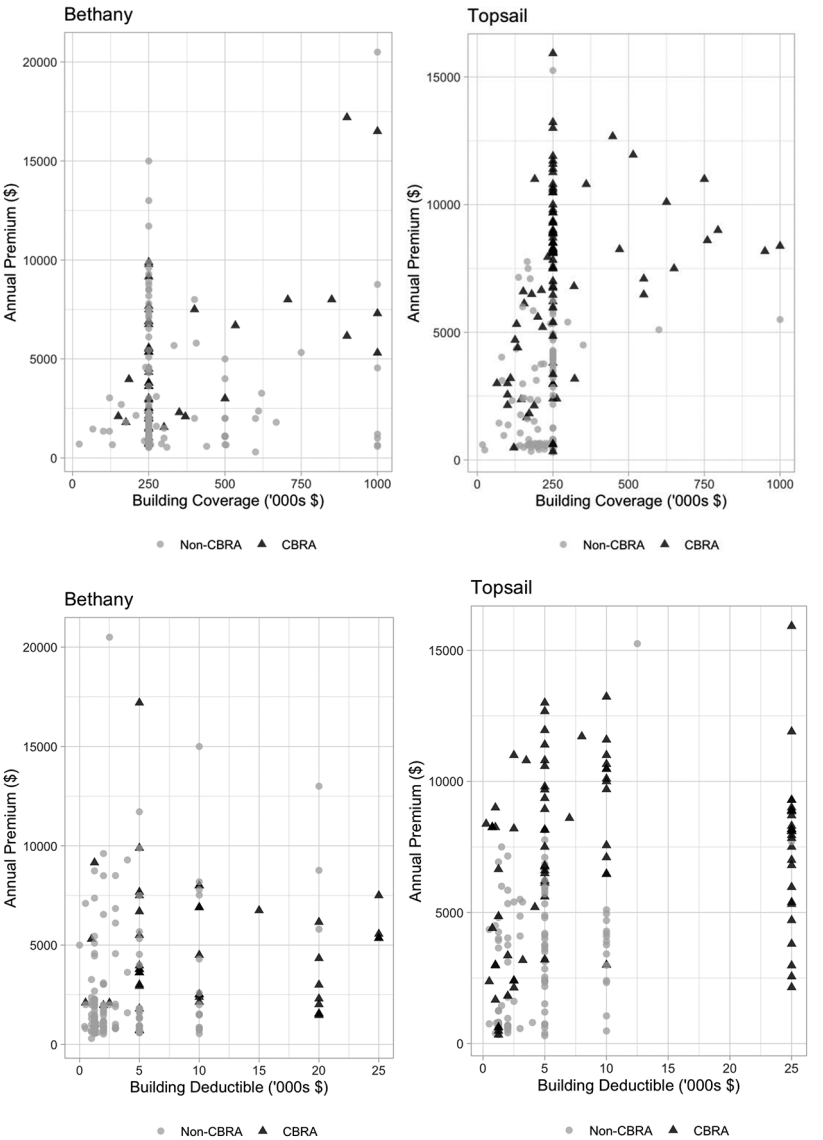

Figure 4. Flood Insurance Premiums by Coverage and Deductible. To simplify the graphs, coverage is truncated at $1 million and deductible is truncated at $25,000. Any policies exceeding those amounts are included as part of the upper bound.

figure also shows that the mean and median North Topsail premiums are higher in the CBRA zones at least in part because people are selecting higher coverage. This will be controlled for in the upcoming regressions.

To recap, when looking at simple differences between premiums in publicly supported markets and private markets, we see a large difference in premiums paid, with private areas paying two to five times as much per unit of coverage. But, as we have pointed out, this simple difference is incomplete. It does not control for differences in coverage, deductibles, and risks differences across the zones. In the Analysis and Models section, we present an analysis controlling for these differences.

RISK PERCEPTION

We also asked respondents about their perception of flood and storm risk. We asked (1) if the threat of storms/floods factored into their decision to purchase property, (2) what they believed to be the probability of a major storm event hitting their coastal region within the next 10 years, and (3) whether they consider their property to be under- or overinsured. The results are shown in table 3.

Overall, the perception of flood risks is higher among North Topsail residents, where the history of storm occurrence is higher and more recent. When we asked if the threat of storms/floods factored into their decision, 29% of North Topsail respondents said yes versus 16% of North Bethany respondents. When asked about the probability of a major storm hitting their coast in the next 10 years, 64% of North Topsail respondents report "high-mid" chance to "near 100%" chance while only 25% of North Bethany respondents put the probability in that range. A reference storm was used in the question to define a major storm event. For Delaware we used Superstorm Sandy and for North Carolina we used Hurricane Fran and Hurricane Mathew.

About half of the respondents in both areas report that they held the right level of insurance. More respondents report being underinsured: approximately 40% in North Bethany and 34% in North Topsail. In North Bethany, those who report being underinsured but with insurance have about 85% as much dollar coverage as those who report either being overinsured or having the right level of insurance. In North Topsail, they have about 89% as much coverage. In a similar vein, in North Bethany, 57% of the underinsured respondents report having flood insurance versus 67% of the not-underinsured respondents. For North Topsail, the difference is wider: 34%

Table 3. Perceptions of Coastal Risk Hazards

	North Bethany Beach			North Topsail Beach		
	Non-CBRA	CBRA	Overall	Non-CBRA	CBRA	Overall
	When you purchased your property, did the threat of storms/floods factor into your decision in any way? (%)					
No	60	55	59	37	35	36
Yes	15	20	16	32	28	29
Somewhat	25	25	25	32	37	35
	What is the probability a major storm event will hit the Delaware/North Carolina coast in the next 10 years? (%)					
Near 0%	2	2	2	0	0	0
Low	15	16	16	1	2	1
Low-mid	27	30	27	7	6	7
Mid (50%)	31	30	30	32	27	29
High-mid	14	7	12	28	24	26
High	10	10	10	22	21	22
Near 100%	2	5	3	11	19	16
	Do you consider yourself under- or overinsured for the storm/flood risks you face? (%)					
Under	21	26	22	14	17	16
Somewhat under	17	23	18	15	20	18
About right	51	42	49	59	49	53
Somewhat over	4	4	4	6	6	6
Over	1	1	1	3	5	4
Sample size	405	136	541	230	301	531

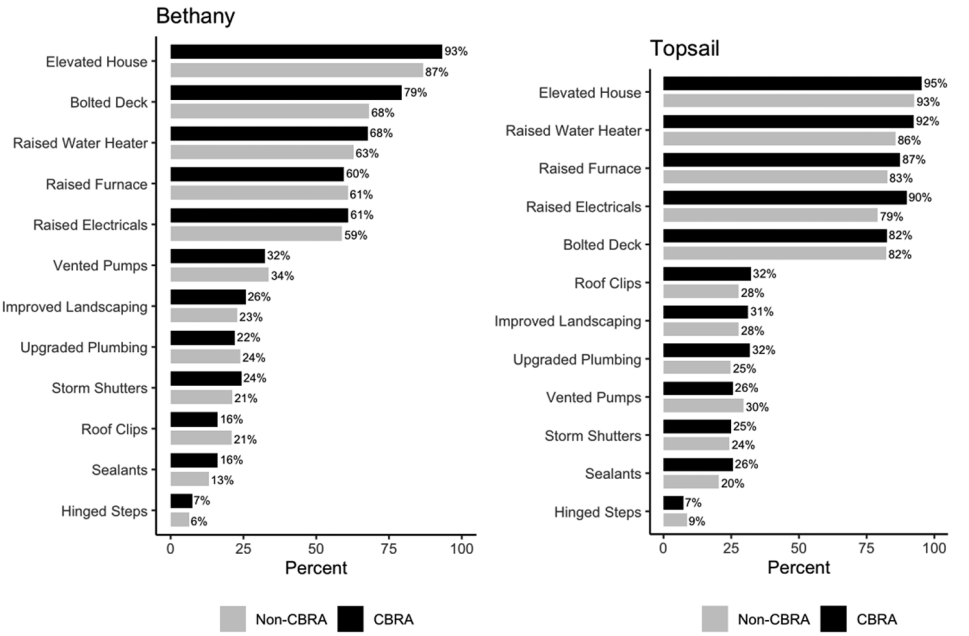

Figure 5. Percentage of Homeowners with a Given Structural Flood Mitigation Measure

underinsured do not have insurance and 60% of not-underinsured do. Households in the CBRA zones, where rates are higher and NFIP is not in effect, are more likely to report being underinsured, suggesting that the federal backing may be achieving its purpose of broadening and increasing coverage. Households are of course free to choose a higher coverage level in CBRA zones and so could, in principle, fix their lack of coverage. Less than 10% of the respondents in both communities report being overinsured. Finally, 17% of North Topsail respondents reported filing at least one flood insurance claim, compared with 2% in North Bethany.

We also asked homeowners about the structural measures in their house to mitigate flood damage. These range from building requirements (the structure being built to a given elevation) to using permeating landscaping and storm shutters. In both communities—in CBRA as well as non-CBRA properties—we found widespread adoption of actions that are either required by a building code or carry financial incentives (through rebates or reduced flood insurance premiums); these actions include raised electrical systems, furnaces, and water heaters. Interestingly, for most of the mitigation measures, CBRA properties held a slightly higher percentage of uptake than non-CBRA properties, as is seen in figure 5. This may be partly due to CBRA homes being newer and lower insurance uptake.

ANALYSIS AND MODELS

HYPOTHESES

Our first null hypothesis is that public and private flood insurance premiums for the same coverage are equivalent. This would support the NFIP's claim that federally backed properties pay an actuarially sound rate. Our second null hypothesis is that households in CBRA and non-CBRA zones have the same propensity to purchase flood insurance. A rejection of this hypothesis provides evidence that the federal program distorts behavior (demand) in insurance markets.

To test the first hypothesis, we compare premiums per-$100-coverage in CBRA and non-CBRA zones. As we have noted, examining simple average differences between the zones can be misleading. Because the communities are similar (nearly indistinguishable), the means are good indicators (indeed this goes to the essence of our study design), but still there may be differences for which we need to account. For example, proximity to the beach is on average higher in the CBRAs in both markets. This will tend to drive up the CBRA premiums relative to non-CBRA premiums and so needs to be controlled for. The next section lays out a series of premium prediction models that control for factors like these. These are simple d-form models where the dependent variable is a household's annual flood insurance premium per-$100-coverage, with covariates for the relevant controls along with a fixed effect for CBRA zone. If the coefficient on *CBRA* is zero or near zero, we accept our hypothesis of no public/private difference.

To test our second hypothesis, we estimated a binary logit model for purchase of flood insurance (yes/no) with covariates for different features of the property, perceptions of the household toward risk, and whether the property is in a CBRA zone. This is a reduced-form model with no explicit theoretical structure. If the coefficient on *CBRA* is zero or near zero, we accept our hypothesis of no public/private difference in insurance uptake. We also have a few ancillary findings, which we will discuss in the upcoming sections.

PREMIUM PREDICTION CONTROLLING FOR EXTRANEOUS FACTORS

We estimate separate reduced-form premium prediction models for North Bethany and North Topsail. The unit of observation is an owner of a single-family residential property. The dependent variable is the reported annual insurance premium divided by coverage, and the policy variable, our treatment, is whether the property is in a CBRA zone. The models also include several control variables to isolate possible effects across the zones.

We consider two models: (1) one using all properties that reported complete insurance coverage data and (2) a second using only those with $250,000 coverage. The latter, as noted earlier, is the market standard for coverage and applies to many of our observations. We use a simple semi-log form in both models:

$$\ln(Premium/Coverage) = \beta_0 + \beta_1 CBRA + \beta_x X + \epsilon, \tag{1}$$

where ln(*Premium/Coverage*) is the natural log of the flood insurance premium divided by coverage; $CBRA = 1$ if the property is in a CBRA zone and $CBRA = 0$ if not; and X is a vector of covariates used to control for other differences. The results are shown in table 4. Although our interest in this model is solely for the purpose of controlling for extraneous influences and not portraying a behavioral model, one may interpret the model as an estimated price schedule for coverage—the outcome of supply and demand forces in the insurance market. In this way, it is like estimating a hedonic price function in a housing or labor market, and is not (as one might be tempted to believe) a demand function for coverage. As with a hedonic price function, a person's willingness to pay for coverage is observed at one point on the price schedule and his/her willingness to pay for coverage at other levels are unobserved, and as such the demand function for coverage is not identified unless data are available from multiple markets or other restrictions are applied.

In all instances our treatment variable (*CBRA*) is statistically significant. In the North Bethany full model, being in the CBRA zone implies a flood insurance premium per unit of coverage that is 2.2 times higher than its non-CBRA counterpart after controlling for other factors. That factor is 2.5 in the $250,000 coverage model. For North Topsail, the CBRA premiums are 2.3 times

Table 4. Semi-Log Reduced-Form Premium Prediction Regressions

	North Bethany Beach		North Topsail Beach	
	Dependent Variable: log(premium/$100 building coverage)			
	Full Model	$250k Coverage Model	Full Model	$250k Coverage Model
CBRA	0.794***	0.903***	0.824***	0.879***
	(0.123)	(0.142)	(0.139)	(0.167)
Pre-FIRM	0.154	0.188	–0.206	0.370*
	(0.109)	(0.118)	(0.143)	(0.202)
	Coverage Bins: Coverage < $250,000 Excluded			
Coverage = $250,000	–0.641***		–0.421***	
	(0.190)		(0.137)	
Coverage > $250,000	–1.172***		–0.732***	
	(0.211)		(0.234)	
	Deductible Bins: Deductible = $5,000 Excluded			
Deductible < $5,000	0.093	–0.085	–0.771***	–0.745***
	(0.096)	(0.107)	(0.137)	(0.171)
Deductible > $5,000	0.072	0.020		
	(0.137)	(0.152)		
Deductible $5,000 to $25,000			0.149	0.299
			(0.181)	(0.209)
Deductible > $25,000			0.066	0.100
			(0.197)	(0.216)
Oceanfront	0.662***	0.771***	0.360***	0.396***
	(0.113)	(0.123)	(0.116)	(0.142)
Row	–0.036**	–0.029		
	(0.016)	(0.018)		
Year purchased	0.003	0.020	–0.001	0.010
	(0.003)	(0.003)	(0.006)	(0.009)
Primary residence	–0.238	–0.233*	–0.311**	–0.550***
	(0.146)	(0.141)	(0.142)	(0.179)
Elevated house	–0.165	–0.012	–0.436*	–0.075
	(0.133)	(0.147)	(0.256)	(0.377)
Mortgage			0.082	–0.045
			(0.129)	(0.152)
Constant	0.059	–0.748***	0.819*	–0.555
	(0.291)	(0.247)	(0.482)	(0.732)
Observations	304	248	234	141
R^2	0.421	0.420	0.501	0.633
Adjusted R^2	0.400	0.398	0.474	0.604
Residual std. error	0.656 (df = 292)	0.631 (df = 238)	0.806 (df = 221)	0.748 (df = 130)
F-statistic	19.326***	19.116***	18.512***	22.395***
	(df = 11; 292)	(df = 9; 238)	(df = 12; 221)	(df = 10; 130)

Note: Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

higher in the full model and 2.4 in the $250,000 model. For comparison, the simple mean differences (per-$100-coverage) in North Bethany and North Topsail are 2.0 and 2.4 times higher. So, controlling for other factors does not have a large effect. Given the similarity of the markets in terms of risk profiles and structure of the houses, this is not a surprise.

Otherwise, the control variables in the models work mostly as expected. The discussion here focuses on the full models. The control variables showing the largest effect are proximity (*Oceanfront* and *Row*) to the water and primary residence (*Primary Residence*). *Oceanfront* increases premiums by 1.93 times (all else constant) in North Bethany and by 1.43 in North Topsail. *Row* in North Bethany tells a similar story: each row farther from the coast lowers premiums about 3.5%. We do not have a row variable in the North Topsail model. Insurance companies charge lower rates for a home that serves as a primary residence (mandated by the Homeowner Flood Insurance Affordability Act of 2014). That discount is about 21% in North Bethany and 27% in North Topsail (see *Primary Residence*). The *pre-FIRM* variable is meant to pick up the discounted effect we would expect to see for properties built prior to FIRM mapping, which explicitly qualify for lower, subsidized rates. This discount is not apparent for North Bethany owners. In North Topsail it is on the order of 19%.

The coverage bins, which are group dummy variables by coverage levels (*Coverage = $250,000* and *Coverage > $250,000*), show that premiums per unit of coverage decline with absolute coverage levels and do so with statistical significance. The excluded group in all models is *Coverage < $250,000*. And finally, the deductible bins (*Deductible < $5,000*, etc.) are poor predictors of premium level. In North Bethany none of the deductible bins are significant statistically, and in North Topsail they are insignificant over the range of high deductibles and significant but in the wrong direction for *Deductible < $5,000*. The excluded group in all models is *Deductible = $5,000*, so we expected the lower bins to have positive signs and higher bins to have negative signs. While we expect within-firm effects to matter (higher deductibles lowering the offered premium), across firms this apparently does not hold.

Finally, as a robustness check we have estimated two other versions of the model: (1) full model without the coverage bins and (2) full model with only CBRA, pre-FIRM, coverage, and oceanfront. These are all tests for the potential of endogeneity, which has not necessarily been purged in full by our primary regressions. The results for the coefficient of interest (*CBRA*) only are in table 5. As shown, the model is reasonably robust to these exclusions, which is a modest endorsement that endogeneity may not be a serious problem.

INSURANCE UPTAKE CONTROLLING FOR EXTRANEOUS FACTORS

In both markets about 75% of the respondents reported having flood insurance in the non-CBRA zones, while only 40% did so in the CBRA zones. This is a 1.875 times higher incidence of coverage in the non-CBRA zones than in the CBRA zones. Given that the publicly supported

Table 5. Robustness Check for CBRA Coefficient

	North Bethany Beach	North Topsail Beach
Full model	0.794***	0.824***
	(0.123)	(0.139)
$250k coverage model	0.903***	0.879***
	(0.142)	(0.167)
Full model without deductible variables	0.869***	1.088***
	(0.108)	(0.136)
Full model including only pre-FIRM, coverage, and oceanfront	0.916***	1.186***
	(0.109)	(0.132)

Note: Standard errors are in parentheses. *** $p < 0.01$.

premiums apply in the non-CBRA zones (lower cost), this stands to reason. There are also some coverage requirements in the non-CBRA zones. Here we consider a model of insurance uptake controlling for extraneous factors like we did in the premium prediction model and test whether being in a CBRA zone affects the likelihood of holding a flood insurance policy. We consider a reduced-form binary logistic regression,

$$\text{pr}(\textit{insured}) = \frac{exp(\beta_0 + \beta_1 CBRA + \beta_x X)}{1 + exp(\beta_0 + \beta_1 CBRA + \beta_x X)}, \quad (2)$$

where pr(*insured*) is the probability of purchasing flood insurance, $CBRA = 1$ if the property is in a CBRA zone and $CBRA = 0$ if not; and X is a vector of covariates used to control for other factors that may influence the purchase of flood insurance. X includes proximity (*Oceanfront, Row*), *Primary Residence* (yes/no), *Mortgage* (yes/no), and self-reported perceptions (*High Storm Perception*, *Purchase Influenced*). The regressions are slightly different for North Bethany and North Topsail. We do not have *Row* (row in which house is located from the beach) in North Topsail and do not have *Mortgage* in North Bethany.[2] Properties with mortgages are usually required to obtain flood insurance by the lending bank. The results are shown in table 6. The sample sizes here are larger than the premium prediction models because of the inclusion of households not purchasing insurance and higher response rates over the variables used in the model. Again, the purpose is prediction and not representation of a behavioral process.

In North Bethany, the model implies that the likelihood of having insurance if you are in a non-CBRA zone is 1.9 times higher than if you are in the CBRA zone, and 2.4 times higher in North Topsail. These are calculated at mean values of the independent variables in the models and give results close to simple mean differences, so the model correction is not large. For North Bethany, *CBRA* was the only variable in the model with significance. In North Topsail, *Oceanfront, Purchase Influenced*, and *Mortgage* are significant. The *Mortgage* variable implies that many households would not purchase flood insurance if they were not required to do so. The other control variables work in the direction one would expect: higher uptake for oceanfront owners, for those whose purchase decision was influenced by the risk of flooding, and for those whose property was not a primary residence.

SUMMARY OF FINDINGS AND POLICY IMPLICATIONS

SUMMARY OF FINDINGS

The purpose of this study is to examine two hypotheses: (1) that private and publicly backed (NFIP) insurance premiums in similar markets are the same, and (2) that insurance uptake is unaffected by offering publicly backed flood insurance. Taking advantage of anomalously developed CBRA coastal areas in Delaware and North Carolina, houses eligible for NFIP policies were compared with houses ineligible for the same policies. Information from homeowners in both markets was gathered by mailed surveys. Our analysis led to several findings.

2. The lack of mortgage data, which is an important predictor in buying flood insurance, was an oversight in the survey design for North Bethany, which was administered prior to the North Topsail survey. We have no reason to believe that *Mortgage* is correlated with our policy/treatment variable, *CBRA*, and so we do not expect this to introduce bias on that coefficient. When we ran the North Topsail model without *Mortgage*, the *CBRA* coefficient estimate changed by ~1%.

Table 6. Logistic Insurance Uptake Regressions

	Dependent Variable: Have Flood Insurance (yes = 1)	
	North Bethany	North Topsail
CBRA	–1.699***	–2.024***
	(0.220)	(0.293)
Oceanfront	0.165	0.641**
	(0.312)	(0.283)
Row	0.006	
	(0.041)	
Primary residence	–0.275	–0.058
	(0.366)	(0.396)
High storm perception	0.554	0.229
	(0.341)	(0.277)
Purchase influenced	0.306	0.680**
	(0.292)	(0.291)
Mortgage		4.348***
		(0.375)
Constant	1.146***	–0.582**
	(0.244)	(0.245)
Observations	508	515
Log likelihood	–283.920	–185.297
Akaike inf. crit.	581.839	384.594

Note: Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$.

In Delaware the median flood insurance premium in the publicly backed non-CBRA zones was $997 per year compared with $3,881 per year in the private-insurance-only CBRA zone. In North Carolina the same comparison is $1,006 and $8,106 per year. Large differences between publicly backed and private insurance are evident. In terms of premiums per unit of coverage and after controlling for extraneous factors across markets in reduced-form regressions, the private versus publicly backed premiums are estimated to be 2.2 times higher in Delaware and 2.3 times higher in North Carolina. If the NFIP were actuarially sound, other things being equal, we would expect the publicly backed and private insurance premiums to be about the same or, at least, only modestly different. Instead, private premiums are more than twice the publicly backed premiums per unit of coverage.

We also found remarkable differences in the premiums offered for houses with the same level of coverage in the same market (see figure 4). In some cases, the difference is more than a factor of five. This may be explained in part by the risk differences, but given the proximity of these properties and identical flood designations, this does not explain the full variation. Interestingly, several respondents noted large disparities in the comments section on our survey—having compared rates among neighbors. The differences, of course, could be due to factors other than risk, such as quality of the insurance provider (service, handling claims, etc.) or perhaps protective actions taken in the house (to lower premiums), but the wide difference is difficult to explain. The result is also not explained by differences in deductibles, which itself has surprisingly little effect on premiums. In short, we observe wide differences in the premiums paid for the same level of coverage (controlling for deductibles) in areas where risks are ostensibly the same.

We find that households are much more likely to purchase flood insurance in federally backed non-CBRA zones than in private CBRA zones. In both Delaware and North Carolina, approximately 75% of the owners had flood insurance in the non-CBRA zones, compared with 40% in CBRA zones. Given the higher rates in the private CBRA zones, this result is not surprising. At the same time, the level of coverage in the non-CBRA zones tends to be lower, when a policy is purchased. In the publicly backed non-CBRA zones, the uptake of flood insurance is significantly higher than in the private CBRA zones, and the chosen coverage levels tend to be lower.

Finally, the perception of a threat of storm in North Topsail was larger than in North Bethany, which is also objectively the case, and is borne out by a larger share of homeowners reporting claims in North Topsail. Over 60% of the households in North Topsail thought there is a "high chance" of a major storm in the next 10 years. In North Bethany, only 25% thought so. At the same time, 30% of North Topsail residents said they factored storms into their purchase decision, compared with 15% of North Bethany residents. Last, in both communities the share of households reporting that they were "underinsured" was greater than 33% and "overinsured" was less than 6%. North Topsail residents perceive a larger threat from future storms and factor it into their purchase decision more so than in North Bethany, but in both communities people tended to feel they were more likely to be under- than overinsured (though most thought they had about the right level of insurance).

POLICY IMPLICATIONS

The NFIP is currently in the process of changing its method for calculating insurance risks and premiums (Risk Rating 2.0) with the intent of helping to bring financial solvency to the program and better capturing the true risk of living in flood-prone areas during changing climate dynamics. Our study supports the arguments behind the need for reform.

With calls for the NFIP to undergo fundamental reform, deeper questions underlying the national flood insurance program are brought forth concerning the role of the NFIP in the current era. Is the dual mandate of providing flood insurance to all and encouraging community floodplain management able to exist alongside the need to remain financially solvent? Do private insurance companies, with more sophisticated catastrophe modeling, have the capacity to fill this gap in accurate risk pricing? Does providing below-market-rate insurance to coastal homeowners encourage moral hazard and risky property investments?

These are fundamental questions concerning the flood insurance industry beyond the scope of this paper. However, our data fill a gap relevant to this discussion by providing empirical data on NFIP versus private provision of flood insurance for equivalent homeowners. Although the NFIP and private providers operate via different models, with different goals and structures, both are ultimately providing risk reduction to homeowners. To what extent the government should provide this service, and to what extent it should be left between homeowners and private insurers, is a question that will continue to be debated. The data presented in the paper depict the contrast between these alternatives and question the notion of NFIP's actuarial soundness.

From an economic perspective, the "implicit subsidy" we find in the NFIP implies that property owners on the coast in the non-CBRA areas, which occupy the vast majority of coast, are paying significantly less than the full cost of the risk of living there. This has efficiency and equity implications. On the efficiency side, it may encourage excess building and excess insurance—more houses and more insurance coverage than we would expect in a private setting (Druckenmiller et al. 2023). On the equity side, since home ownership on the coast is mostly by higher income

(and higher wealth) households, the policy is likely to be regressive. Is this a public need for which taxpayers should be footing the bill? Current legislation in this regard appears to be moving in an efficiency- and equity-improving direction.

The similarity of premium levels in Delaware and North Carolina under federally backed policies (see table 2) also points to the likelihood that the NFIP rates are not adequately accounting for risk differences in the regions given the differences in their objective risks, which implies inefficiency and inequity spatially. One would hope to discourage development in riskier areas, and if subsidies are provided to do so, at rates that would at least result in comparable long-term payouts. One would hope this is an adjustment being made in Risk Rating 2.0.

Finally, and along other lines, behavioral economists might seize upon our finding that households more often report being underinsured than overinsured and argue for a nudge of some sort—perhaps an explicit requirement to be offered insurance *forcing* households to opt out. Other types of nudges may be possible.

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