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4 Does removal of federal subsidies discourage urban development? An  
5 evaluation of the US Coastal Barrier Resources Act

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19 **Abstract**

20 Urban development relies on many factors to remain viable, including infrastructure, services,  
21 and government provisions and subsidies. However, in situations involving federal or state level  
22 policy, development responds not just to one regulatory signal, but also to multiple signals from  
23 overlapping and competing jurisdictions. The 1982 U.S. Coastal Barrier Resources Act (CoBRA)  
24 offers an opportunity to study when and how development restrictions and economic  
25 disincentives protect natural resources by stopping or slowing urban development in  
26 management regimes with distributed authority and responsibility. CoBRA prohibits federal  
27 financial assistance for infrastructure, post-storm disaster relief, and flood insurance in  
28 designated sections (CoBRA units) of coastal barriers. How has CoBRA's removal of these  
29 subsidies affected rates and types of urban development? Using building footprint and real estate  
30 data ( $n=1,385,552$  parcels), we compare density of built structures, land use types, residential  
31 house size, and land values within and outside of CoBRA units in eight Southeast and Gulf Coast  
32 states. We show that CoBRA is associated with reduced development rates in designated coastal  
33 barriers. We also demonstrate how local responses may counteract withdrawal of federal  
34 subsidies. As attention increases towards improving urban resilience in high hazard areas, this  
35 work contributes to understanding how limitations on infrastructure and insurance subsidies can  
36 affect outcomes where overlapping jurisdictions have competing goals.

37

38     

## Introduction

39           Decades of US government policy have prompted extensive private development in  
40   hazardous coastal areas, where there is substantial risk to life and property<sup>1</sup>. In particular, federal  
41   financial assistance has been key to facilitating the construction of critical physical  
42   infrastructure, including highways and bridges, water supply and wastewater treatment facilities,  
43   beach stabilization projects, disaster assistance, and subsidized flood insurance.<sup>2-4</sup> After a major  
44   coastal storm or hurricane impacts a coastal barrier, federal disaster relief helps rebuild damaged  
45   properties and infrastructure.<sup>5-7</sup> Federal financial assistance has helped to perpetuate a cycle of  
46   coastal development, rising rates of hazard-related destruction, and subsidized post-disaster  
47   redevelopment.<sup>4,8,9</sup>

48

49           This study evaluates the long-term effects of withdrawing federal subsidies for urban  
50   infrastructure and flood insurance on urban development in sensitive coastal barriers. How  
51   effective are policies that aim to limit development in hazardous or environmentally sensitive  
52   areas by eliminating infrastructure and disaster recovery funding? How do these restrictions fare  
53   under management regimes with distributed authority and responsibility?

54

55           In this paper, we focus on the unique case created by the 1982 U.S. Coastal Barrier  
56   Resources Act (“CoBRA”; 16 U.S.C. 3501 et seq.)<sup>10</sup>, which prohibits federal financial  
57   assistance (e.g., loans, grants, flood insurance, rebates, subsidies, or financial guarantees) for  
58   roads, bridges, utilities, erosion control, and post-storm disaster relief in statutorily designated  
59   sections of US coastal barriers. These areas, which we will call “CoBRA units,” comprise the  
60   John H. Chafee Coastal Barrier Resources System.<sup>11</sup>

61  
62       Homeowners in CoBRA units are ineligible for subsidized flood insurance through the  
63       National Flood Insurance program (NFIP), while homeowners in adjacent, non-CoBRA areas  
64       are eligible. Moreover, CoBRA units may be subject to other types of development  
65       disincentives (e.g., additional subsidy restrictions) and land protections (e.g., zoning) enacted by  
66       other entities such as local and state government, private agencies, and other federal agencies.  
67       However, some CoBRA units may also be subject to development *incentives*, possibly the result  
68       of local governments replacing the federal subsidies removed by CoBRA.

69  
70       The intent of this paper is to explore the impact of CoBRA on designated coastal  
71       barriers. In particular, we investigate the extent to which development has remained low in  
72       CoBRA units, in areas with other land use controls, and in areas with restrictions from both  
73       CoBRA and local land use controls. We also examine relationships between CoBRA and  
74       residential property values, and associations between development densities within and outside  
75       of CoBRA units.

76  
77       We employ a cross-sectional approach to analyze differences in development across  
78       different combinations of development disincentives. We then compare distributions of building  
79       density, land use, house size, and land values across different combinations of development  
80       disincentives and regulations. Our study area extends 2 km inland from the coastlines of the  
81       eight Gulf Coast and Southeast states (Alabama, Florida, Georgia, Louisiana, Mississippi, North  
82       Carolina, South Carolina, and Texas). This area comprises 76% of all land in CoBRA units and  
83       81% of land in Otherwise Protected Areas (OPA units), discussed below (Table 2).

84

85        Our analysis reveals a nuanced relationship between CoBRA and development patterns,  
86        including instances where the removal of federal subsidies may have been either counteracted  
87        or reinforced by state and local responses. This work has implications for understanding how  
88        the removal of development subsidies can affect desired outcomes in light of overlapping  
89        jurisdictions with competing goals and distributed authority and responsibility.

90

## 91        **Background**

### 92        **Growth management and coastal development risk**

93        There are many ways that government policy might be designed to reduce development  
94        risks, including attempts to restrict urban development in areas facing high risks of coastal  
95        hazards. Studies of urban management regimes and growth control policies have typically  
96        focused on understanding where development occurs and the characteristics of development in  
97        relation to urban services and targeted subsidy provisions.<sup>12–14</sup> However, much of this work has  
98        characterized growth management programs as being designed and implemented across large  
99        areas, often by a single agency, without considering heterogeneity in implementation.

100

101        In their classic study on implementation, Pressman and Wildavsky argue that programs  
102        fail because implementing agencies are thwarted by inter and intra organizational politicking and  
103        signaling after policies and programs have been adopted.<sup>15</sup> Within the context of large-scale  
104        infrastructure provision, multiple entities are often responsible for infrastructure financing and  
105        regulation, each of which may have competing agendas and different incentives. As a result,

106 development patterns typically respond to multiple, regulatory and investment signals (e.g., US  
107 federal and state infrastructure funding) from overlapping and competing jurisdictions.<sup>16-18</sup> Few  
108 studies have explored instances where differential implementations of development management  
109 policies arise from interactions among jurisdictions at different levels (e.g., federal, state, and  
110 local). How effective are policies that aim to limit development in hazardous or environmentally  
111 sensitive areas by eliminating infrastructure and disaster recovery funding? How do these  
112 restrictions fare under management regimes with distributed authority and responsibility? Using  
113 the 1982 Coastal Barrier Resources Act as a case study, this study evaluates the long-term effects  
114 of withdrawing federally-funded urban infrastructure and flood insurance subsidies for  
115 development on sensitive coastal barriers.

116

## 117 **The 1982 U.S. Coastal Barrier Resources Act (“CoBRA”)**

118 As an environmental policy, the 1982 U.S. Coastal Barrier Resources Act represents a  
119 novel vehicle for exploring the role of federal subsidies in promoting or inhibiting development  
120 in environmentally sensitive areas. CoBRA’s purpose is to 1) minimize loss of life, 2) reduce  
121 wasteful expenditures of federal revenues and 3) protect fish, wildlife, and other natural  
122 resources.

123

124 The prohibitions on federal expenditures went into effect immediately after the law’s  
125 passage (October 18, 1982), while those for federal flood insurance did not become effective  
126 until one year later (October 1, 1983). Congress initially designated 186 CoBRA units, totaling  
127 some 453,000 acres (~183323 ha) along 666 miles (~1072 km) of shoreline of the Atlantic and  
128 Gulf coasts. CoBRA was expanded and modified by Congress in 1990 to include “Otherwise

129 Protected Areas" (OPAs), areas identified by Congress as being protected by other means (such  
130 as National and State parks), and for which federal subsidies other than flood insurance would  
131 be allowed.<sup>19</sup>

132

133 Flood insurance refers to the federally subsidized National Flood Insurance Program or  
134 "NFIP". Communities that meet certain federal standards for floodplain management may  
135 participate in the NFIP. Homeowners and renters in participating communities are eligible to  
136 (voluntarily) purchase flood insurance from the Federal Emergency Management Agency  
137 (FEMA). Some 22,000 communities participate in the NFIP.<sup>20</sup> In addition, under FEMA's  
138 Community Rating System, communities can implement activities that go beyond the minimum  
139 requirements of NFIP and in return, policyholders in those communities may qualify for  
140 discounts on their federal flood insurance premiums. As of 2017, over 1400 communities  
141 participate in CRS.<sup>21</sup>

142

143 Congress retains the sole authority to modify CoBRA unit boundaries upon the  
144 recommendation of the US Fish and Wildlife Service (FWS). Areas initially designated for  
145 inclusion were those (in 1982) with a) less than one walled and roofed building per five acres  
146 (~2 ha) of "fastland" (i.e., land above mean high tide), b) areas lacking urban infrastructure,  
147 vehicle access, water supply, wastewater disposal, and electric service to each lot, and c) areas  
148 that were not part of a development of 100 or more lots. In addition, designated units had to  
149 have at least one-quarter mile (0.4 km) of oceanfront.<sup>22</sup> Little community input was taken when  
150 designating units; some units were withdrawn from, and others added to, the system over time,

151 with each change requiring an act of the US Congress.<sup>23</sup> Since the 1990 amendments, the Act  
152 has otherwise remained largely unchanged.

153

## 154 **CoBRA, policy resistance, and development pressure**

155 Several studies have questioned the effectiveness of CoBRA. Investigations of random  
156 samples of CoBRA units by the United States Governmental Accountability Office (GAO) in  
157 1992 and 2007 identified continuing development in many CoBRA units, which was facilitated  
158 by numerous, documented actions by local, state, and federal agencies. Case studies have  
159 discovered efforts by state and local governments to encourage development in CoBRA units,  
160 sometimes by substituting their own subsidies for those withdrawn by the federal  
161 government.<sup>22,24-26</sup> However, with the exception of the GAO's 2007 study, no efforts have been  
162 made to comprehensively track or explain development in CoBRA units, and no studies have  
163 attempted to systematically account for other factors that may influence development in coastal  
164 areas, such as state or local development incentives or restrictions.

165

166 While the research available on CoBRA has been meager (particularly over the last ten  
167 years<sup>27,28</sup>), the act nevertheless provides the conceptual basis for considering analogues and  
168 generating hypotheses about the impact of CoBRA on development in designated coastal  
169 barriers. Retrospective analysis can now help understand how, for over 30 years, CoBRA has  
170 shaped development patterns.

171

172 While CoBRA does not regulate land use, it transfers some of the cost of development  
173 (e.g., infrastructure and flood insurance) to the private sector or to state and local governments.

174 CoBRA designation is structurally similar to growth management instruments, such as urban  
175 service and growth boundaries, which have been widely used to restrict urban expansion and  
176 protect natural resources, such as farmland.<sup>29,30</sup> Urban service boundaries (USBs) do not  
177 prohibit development, but instead set expectations that services, such as sanitary sewers and  
178 water supply, are not publicly provided outside their specified areas. There is conflicting  
179 evidence regarding the effectiveness of USBs in containing low density urban expansion and  
180 requisite infrastructure development.<sup>31,32</sup>

181

182 Similarly, urban growth boundaries (UGBs) seek to restrict the area where  
183 development can occur in a jurisdiction. Like USBs, UGBs also preserve amenities (e.g.  
184 open space) whose value are internalized into higher land and housing prices, where  
185 development is allowed,<sup>33</sup> or increased development densities.<sup>34–36</sup> However, these effects  
186 are diluted when political pressure and built-in mechanisms for changes to UGB geographic  
187 delineations weaken the market signal intended to concentrate development intensity into  
188 core urban centers.<sup>37,38</sup> We contend that the same pressures in USBs and UGBs can occur in  
189 CoBRA units that border expanding urban areas--an effect that can be mediated by regional  
190 development pressure (i.e., regional economic growth).

191

## 192 **Hypotheses**

193 In this paper, we use a cross-sectional approach to analyze differences in development  
194 across different combinations of development disincentives. Since CoBRA units were almost  
195 exclusively designated in areas with development densities lower than one structure per five  
196 acres (~2 ha) as of 1982, there is the potential that land that was designated was unattractive for

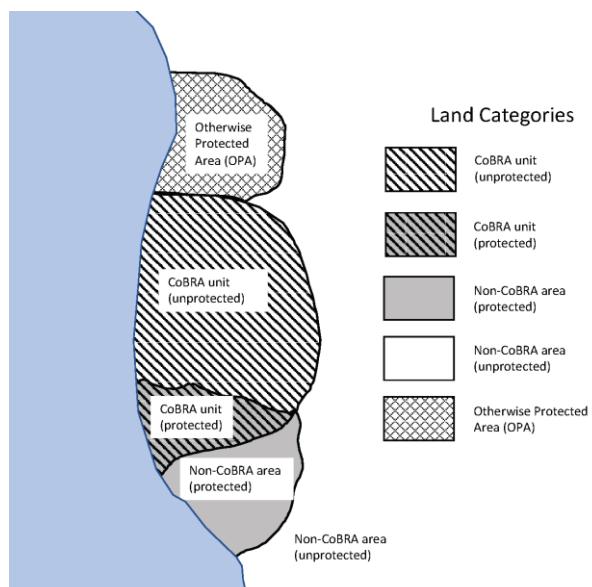
197 development in the first place and potentially correlated with becoming part of CoBRA. We do  
198 not attempt to resolve this endogeneity problem and instead present our findings as exploratory  
199 and descriptive.

200

201 We conceptualize three levels of restrictions and regulations affecting coastal  
202 development (explained in more detail in the Study Area section), which can be configured to  
203 categorize coastal land into five categories or types, shown in Table 1 and depicted in Fig 1. The  
204 three restrictions include NFIP eligibility, other federal expenditures (e.g., for roads or sewer  
205 systems), and restrictions on urban development (e.g., designation as protected lands). Table 1  
206 also shows our four hypotheses (H1 – H4) based on our five categories of land.

207

208 **Fig 1: Depiction of land categories and their overlaps**



209

210

211 **Table 1: Land categories by coastal development disincentive/regulations and hypotheses (H1-4)**

Land Category	Eligible for flood insurance (NFIP)?	Eligible for other federal spending?	Is urban dev. unrestricted?	H1: CoBRA reduces dev. intensity	H2: CoBRA interacts with protected areas	H3: CoBRA creates a luxury effect for dev. parcels	H4: Dev. pressure spills into CoBRA units
Non-CoBRA area, unprotected (Type 1)	Yes	Yes	Yes				If high dev. rate, then Type 1&4 dev. rates are similar
Non-CoBRA area, protected (Type 2)	Yes	Yes	No	Less dev. than Type 1			
OPA (Type 3)	No	Yes	No	Less dev. than Type 1	More dev. than Type 5		
CoBRA unit, unprotected (Type 4)	No	No	Yes	Less dev. than Type 1		Dev. property values: higher than Type 1	
CoBRA unit, protected (Type 5)	No	No	No	Less dev. than Type 1	Less dev. than Type 2 and 4	Dev. property values: Higher than Type 2	

212 “Protected” status = areas specified in USGS Protected Areas Database, which includes lands protected or managed for purposes of

213 government use, recreation, and habitat conservation. “dev.” = development or developed. OPA = Otherwise Protected Areas.

214

215            We aim to test four hypotheses (H1-4; Table 1). We first (H1) hypothesize that CoBRA  
216    affects land markets by increasing development costs (and therefore decreasing development  
217    extent) in CoBRA units as a result of higher, non-subsidized infrastructure and flood insurance  
218    costs. However, CoBRA's impact might be weaker than outright protection through designation  
219    as a conservation area such as a park (e.g., by state or local government). Thus, we expect that  
220    parcels in unprotected CoBRA units and OPAs (as documented in the USGS Protected Areas  
221    Database, described below) experienced less extant overall development than non-CoBRA areas,  
222    where the CoBRA and non-CoBRA areas are not subject to other restrictions on land use.

223

224            Second (H2), we expect that withdrawal of federal subsidies acts synergistically with  
225    direct development restrictions (e.g., easements or other land use controls), resulting in less  
226    overall development in CoBRA units where the restrictions apply, than in CoBRA units where  
227    they do not. We also expect less development in protected CoBRA units than in protected non-  
228    CoBRA areas, as only the CoBRA units face the additional cost of non-federally subsidized  
229    infrastructure, disaster recovery, and flood insurance. The OPAs also offer a salient contrast, by  
230    providing explicit federal recognition of some, but not all areas with development restrictions,  
231    and withdrawing flood insurance subsidies from them. We expect land in OPAs, by virtue of  
232    being eligible for federal subsidies other than flood insurance, to be marginally more developed,  
233    than protected CoBRA units that are subject to restrictions, but not recognized as OPAs.

234

235            Third (H3), we expect there to be countervailing influences of CoBRA on property  
236    values. The withdrawal of federal subsidies under CoBRA, coupled with other development  
237    restrictions (e.g., easements or other land use controls),-should tend to depress land values and

238 increase development costs. However, in some cases, the low-density and secluded nature of  
239 land in CoBRA could make these areas attractive to development.<sup>39</sup> Under these circumstances,  
240 we suspect the property values for comparable properties may be higher in CoBRA units than in  
241 non-CoBRA areas.

242

243 Our final hypothesis (H4) concerns the regional heterogeneity and spatial dependence of  
244 CoBRA's effects. In cases where development pressures are strong enough due to lack of  
245 developable land in neighboring, non-CoBRA areas, or where other actors – such as local or state  
246 governments – assume the burden of replacing foregone federal subsidies, we hypothesize that  
247 development rates in unprotected CoBRA units would resemble those in *proximate*, unprotected  
248 non-CoBRA areas. This suggests a range of potential situations, including CoBRA units that  
249 develop very little, if at all, and others that develop at comparable rates as nearby non-CoBRA  
250 areas.

251

## 252 **Materials and Methods**

### 253 **Study Area**

254 Our study concerns the coastline along the U.S Gulf Coast and Southeast Coast in eight states,  
255 Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas  
256 (Table 2). In order to compare development patterns within CoBRA units to comparable non-  
257 CoBRA areas, we first restricted our study area to land within 2 km of our study states'  
258 coastlines. Looking beyond areas proximate to coastal barriers could lead to statistical  
259 misspecification problems as significantly different economic and social dynamics affect inland  
260 and coastal barrier development patterns.<sup>40</sup>

261 **Table 2: Extent of Coastal Barrier Resources System units (“CoBRA units”) and Otherwise**  
 262 **Protected Areas (OPAs) in eight study states. Fastland refers to land above the mean high**  
 263 **tide line.**

	Unit count		Fastland (ha)		Shore length (km)	
	CoBRA	OPA	CoBRA	OPA	CoBRA	OPA
Alabama	4	6	3,586	6,333	33	27
Florida	68	63	54,354	116,809	375	375
Georgia	6	7	13,729	98,095	35	121
Louisiana	17	4	18,803	6,830	315	175
Mississippi	6	1	494	2,058	107	63
North Carolina	9	7	15,425	43,422	69	241
South Carolina	16	7	25,853	9,897	33	77
Texas	17	18	116,475	174,942	270	227
Sample total	143	113	248,719	458,387	1,242	1,306
Entire CBRS	585	277	329,215	566,040	2,282	2,042
% of entire system represented	24%	41%	76%	81%	54%	64%

264 We overlaid GIS shapefiles delineating CoBRA units and OPAs<sup>41</sup>, as well as the USGS  
 265 Protected Areas Database<sup>42</sup>, which is a geospatial database of protected areas that are  
 266 “...dedicated to the preservation of biological diversity and to other natural (including  
 267 extraction), recreation and cultural uses, managed for these purposes through legal or other  
 268 effective means.” This procedure resulted in land area being sampled and classified from 85  
 269 coastal counties, 77 of which contained at least one CoBRA unit.

270  
 271 Our primary units of analysis were individual land parcels. We retrieved these geospatial  
 272 cadastral data from the National Parcel Data Portal, a proprietary aggregation of county-based  
 273 georeferenced parcel polygons available from Boundary Solutions, Inc.<sup>43</sup> Nearly 46% of the total  
 274 area of our study parcels is overlapped by CoBRA units or OPAs, and 62% of the total area is  
 275 within a protected area or in a CoBRA unit. Using these overlays, we classified each parcel into  
 276 one of the five development disincentive categories (Table 1): unprotected, non-CoBRA areas

277 (Type 1), protected, non-CoBRA areas (Type 2), OPAs (Type 3), unprotected, CoBRA units  
278 (Type 4), and protected CoBRA units (Type 5). Where parcels were split by CoBRA units,  
279 OPAs, or protected areas, we classified the parcel as the category for which it had the greatest  
280 portion of its area within.

281

## 282 **Data**

283 For parcels within our sample area, we sourced current property characteristics from the  
284 2016 vintage of the ZTRAX transactions database produced by Zillow, which is made available  
285 to researchers upon request, subject to a Data Use Agreement.<sup>44</sup> Using county assessor parcel ID  
286 numbers, we matched ZTRAX real estate data to the parcel polygons. The variables retrieved  
287 from ZTRAX for this analysis include a nationally standardized land use code (which we  
288 summarize into eight different categories, as described in the “Land Use Comparison” sub-  
289 section), the year built of each structure on a parcel (if any), the most recent sales price in USD,  
290 the recording date of the most recent sale, and the square footage of each structure on the parcel  
291 (see Supplementary Table 1).

292

293 In order to create an inventory of development density, we counted structures within  
294 parcels and measured the percentage of each parcel covered by structures using spatial  
295 intersection queries from the *sf* package in the R statistics software<sup>45</sup>. Our source for structures  
296 and building footprints is a dataset of 125,192,184 computer generated building footprints in all  
297 50 US states in GeoJSON format, which was produced and distributed by Microsoft, Inc. under  
298 the Open Data Commons Open Database License<sup>46</sup>. These footprints were generated from high-  
299 resolution aerial photographs taken between 2014 and 2016.

300

301 **Land Use Comparison**

302         Using ZTRAX's nationally harmonized land use categorization, we classified each parcel  
303         into one of eight summary land use categories: *government/military*, *residential-single family*,  
304         *residential-multipamily*, *other developed*, *open space*, *agriculture*, *zoned vacant lots*, and *other or*  
305         *not classified*. We then computed the proportional cross-tabulation of total area represented by  
306         parcels by development disincentive category (see Table 1) and by land use category.

307

308         *Government/military* includes government offices, military facilities, and government-  
309         owned land restricted to the public. Urban or developed land uses are divided into *Residential-*  
310         *single family*, *residential-multipamily*, and *other-developed land uses*. *Residential-single family*  
311         includes detached residences and mobile homes. *Residential-multipamily* includes apartments,  
312         duplexes, townhomes, condominiums, and mobile homes. *Other-developed* includes all other  
313         kinds of development other than government or agricultural, including non-governmental  
314         institutions, commercial, industrial, and recreational structures.

315

316         Undeveloped land has many land use categories represented in ZTRAX, which we  
317         aggregate to *open space*, *agriculture*, *zoned vacant lots*, and *other or not classified* land uses.  
318         *Open space* refers to land designated as parks, conservation areas, and similar open space areas  
319         with defined land uses. *Agriculture* refers to any agricultural use. *Zoned vacant lots* refer to  
320         parcels that have been zoned for – and are often surrounded by – residential, commercial,  
321         industrial, or institutional structures, but have no structures on them. *Other or not classified*

322 parcels do not have designated land uses and generally represent unused, undeveloped, but not  
323 necessarily protected land.

324

## 325 **Parcel Characteristic Comparison**

326 We estimated a series of linear regression equations of the form in Equation 1.

327 
$$y_{ij} = \alpha_j + \Sigma \beta C_i + \epsilon \quad (1)$$

328 In Equation 1,  $i$  indicates parcel,  $j$  indicates county,  $\alpha_j$  indicates county fixed effects, and  $C$  is a  
329 vector of dummy variables indicating whether parcel  $i$  is in each of the development disincentive  
330 categories. These regressions constructed confidence intervals around the difference in the  
331 average value of  $y$  between parcels in unprotected, non-CoBRA areas (Type 1; base category)  
332 and each of the other categories. We estimated regression equations for five dependent variables:

- 333 1. % area of parcel covered by structures [for only developed parcels (parcels with at least  
334 one structure)]. This is a relative measure of building form and extent.
- 335 2. % area of parcel covered by structures [for all parcels]. This is the measure we use to  
336 determine and generalize development extent and/or development rate.
- 337 3. log(residential area (m<sup>2</sup>)) [residential units only]. This measure indicates relative housing  
338 size.
- 339 4. log(most recent sales price (inflation adjusted to 2016 USD)/(residential area (m<sup>2</sup>)))  
340 [residential units only]. This measure normalizes land values to residential units per area.
- 341 5. (residential area (m<sup>2</sup>))/(parcel area (m<sup>2</sup>)) [residential units only]. This measure normalizes  
342 residential construction extent at the parcel level.

343 We estimated these regressions with and without county fixed effects to assess if different  
344 patterns emerge at an overall level or when controlling for local conditions. We also estimated a

345 series of Hierarchical Linear Models (HLM) as a check on the robustness on our models with  
346 county fixed effects; we fit a multi-level random intercept model, with parcels nested in counties  
347 and counties nested in states.

348 
$$y_{ics} = \alpha_{cs} + \Sigma \beta_i T_i + \epsilon_{ics}$$

349 
$$\alpha_{cs} = \gamma_s + u_{cs}$$

350 
$$\gamma_s = \delta + \eta_s$$

351 Where  $T_i$  are the treatments of interest and c and s refer to counties and states respectively. We  
352 find no substantial differences in estimates or significance levels and therefore choose to present  
353 our fixed effects results given their ease of interpretation. The results of the HLM are presented  
354 in Supplementary Table 3.

355

## 356 **Regional Heterogeneity**

357 We probed for regional heterogeneity in the patterns of development within and outside  
358 of CoBRA units by conducting a cluster analysis at the county level (on land within each county  
359 that is within the study area, excising land that is outside the study area). Our aim was to explore  
360 whether there was variation in the development of land in CoBRA units compared with  
361 neighboring, non-CoBRA areas.

362

363 We first removed from counties any area that is open water, although we left wetlands, which  
364 have been dredged and filled for development in many areas. To remove open water from county  
365 polygons, we employed the 2016 National Land Class Dataset (NLCD), whose 30m raster land  
366 cover data is consistent across the United States.<sup>47</sup> For each county that has at least one CoBRA  
367 unit, we construct the following variables:

368 1. The inverse hyperbolic sine transform (arcsinh) of (structures/hectare in non-CoBRA  
369 areas)

370 2. The inverse hyperbolic sine transform (arcsinh) of structures/hectare in CoBRA units and  
371 structures/hectare in OPAs

372 3. Proportion of area in CoBRA that is designated as OPA (for the rest of our analysis, we  
373 consider OPA and CoBRA units to be exclusive)

374 We then standardized these variables to a common scale, constructed a distance matrix based  
375 on Manhattan distances, and clustered the counties with Ward's hierarchical clustering  
376 algorithm.<sup>48</sup> We used the resulting dendrogram to generate three clusters corresponding to  
377 distinct development patterns across system and non-CoBRA areas within counties.

378

379 Data management and analysis was performed in ArcGIS 10.4 and the R statistical  
380 software<sup>49</sup>, with geospatial data processing in R performed using functions from the *sf* package<sup>45</sup>.  
381 Maps were produced in ArcGIS 10.4, and figures produced with R using ggplot2. Replication  
382 code and data (excepting restricted parcel boundaries and data) are available from the UNC  
383 Dataverse.<sup>50</sup>

384

## 385 Results and Discussion

386 Overall, we found that development rates remained lower and qualitatively different in  
387 CoBRA units compared to non-CoBRA areas (H1). However, there are significant outliers (H3  
388 and H4). As of 2016, 34 of the 257 CoBRA units (13%) in our study area had development  
389 densities that would have precluded their designation if CoBRA were enacted today (i.e., greater  
390 than one dwelling unit per five acres [ $\sim 2$  ha] of fastland).

391

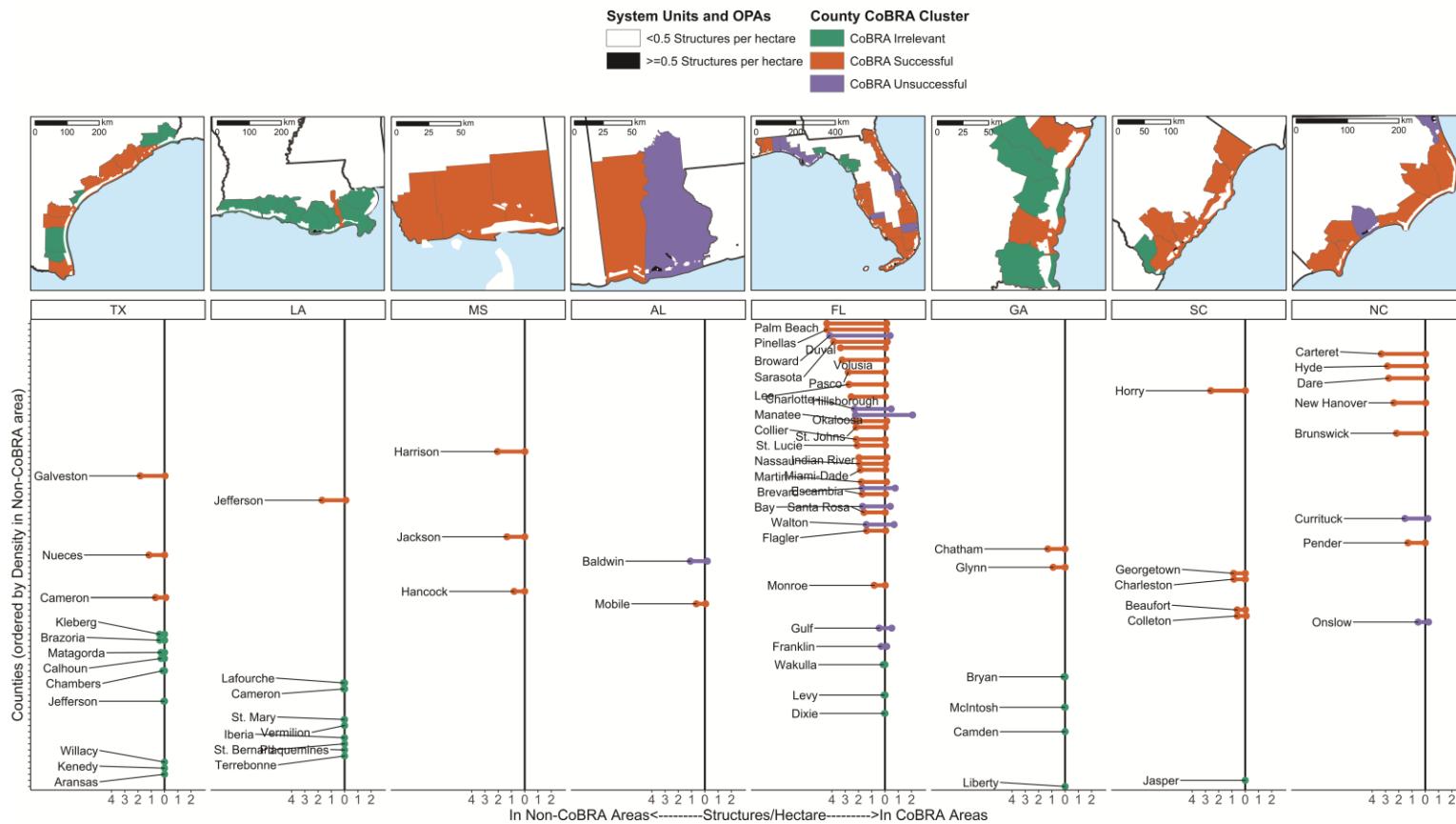
392        This pattern of local exceptions to a generally effective policy is consistent with  
393        heterogeneity in program implementation or effectiveness (H4). Effectiveness could be  
394        undermined by federal agencies circumventing or otherwise ignoring CoBRA, state and local  
395        government agencies filling in subsidy gaps (H3), or by developers providing infrastructure  
396        directly.<sup>20-23</sup> Alternatively, a relatively ineffective policy may be strengthened by  
397        complementary actions of other agencies.

398

399        Cluster analysis of the 77 counties in our eight states with CoBRA units identified three types of  
400        counties describing general patterns of development densities within and outside of CoBRA  
401        units, suggesting substantial regional variability in the effectiveness of CoBRA (H3 and H4; Fig  
402        2).

403

404 **Fig 2: Panel A: Counties with CoBRA units or OPA locations in each of the eight study**  
405 **states. Panel B: Density of built structures (2016) in CoBRA units (right) and non-CoBRA**  
406 **areas (left) by county. Although our analysis extent covers only areas within 2 km of the**  
407 **coastline in counties with CoBRA units, for legibility this figure depicts the entire counties**  
408 **that were part of our analysis. CoBRA units in white or black (for high density) Legend**  
409 **coloring in both panels depicts results of cluster analysis of development rates (n=77**  
410 **counties with CoBRA units) into three categories, where CoBRA could be identified as**  
411 **Successful, Unsuccessful, and Irrelevant.**



414        Twenty-one counties formed a cluster that we call, “CoBRA Irrelevant,” where coastal  
415    development density in both CoBRA units and adjacent non-CoBRA areas was very low,  
416    suggesting an absence of development pressure that could have yielded significant  
417    development. Another 45 counties formed a cluster we call, “CoBRA Successful,” characterized  
418    by near-zero development in CoBRA units and significant development in nearby non-CoBRA  
419    areas (H1). We use the term “successful” here cautiously, as the CoBRA units in these areas  
420    may represent land that was particularly costly or unsuitable for development with or without  
421    the federal funding prohibited by CoBRA. However, despite this endogeneity concern, this set  
422    of counties can be characterized as having a strong difference in development rates within and  
423    outside of CoBRA units between 1980 and 2016.

424

425        The remaining 11 counties formed a cluster characterized by significant development  
426    within system-units relative to nearby non-CoBRA areas, which we refer to as, “CoBRA  
427    Unsuccessful.” Notably, these 11 counties exist entirely in Florida (8), Alabama (1), and North  
428    Carolina (2) (see maps in Fig 2). While this clustering within three states may indicate  
429    overriding roles played by specific state policies, it is important to note that, in these states,  
430    there are an additional 30 counties with CoBRA units that remain undeveloped. Additionally, it  
431    is difficult to study state-level impacts without having high-quality data on policy changes over  
432    time (as state policies affecting activities in CoBRA units have been dynamic), which is beyond  
433    the scope of the current study.

434

435        The counties in this “CoBRA Unsuccessful” cluster exhibited a wide range of  
436    development densities in non-CoBRA areas, from among the densest (e.g., 10.28/ha in Broward

437 County, FL) to the sparsest (e.g., 1.07/ha in Gulf County, FL). It is possible that, in counties  
438 with lower densities in non-CoBRA areas, CoBRA units held more developable or desirable  
439 land than the non-CoBRA areas, such that the incentives to develop could override the lack of  
440 federal subsidies (H3/H4). However, since a similar dynamic does not regularly appear in the  
441 highest-density counties, most of which are in the “CoBRA successful” cluster (see Fig 2B),  
442 development pressure spillovers from proximate land may not be the primary driver of the  
443 development of CoBRA units (H4). Instead, we hypothesize that a combination of local  
444 conditions, including the actions of state and local government agencies, may play significant  
445 roles (H4).

446

447 One important policy that appears to interact with CoBRA-related federal funding  
448 withdrawals is federal, state and local direct development restrictions (H2). Within non-CoBRA  
449 areas, the average parcel size is six-times larger in protected areas than unprotected areas,  
450 suggesting that protection could be discouraging the subdivision of land that generally precedes  
451 urban development (Table 3).

452

453 An alternative explanation is that development restrictions that we characterize in this  
454 study as “protection,” create a luxury effect (H3) that tends to incentivize development of  
455 homes on larger lots.<sup>36</sup> CoBRA may act in complementary ways, as average parcel sizes in  
456 CoBRA units and OPAs are 2.5 – 15 times larger than parcels in protected, non-CoBRA areas.  
457 OPAs, which combine federal flood insurance program prohibitions with notable federal and  
458 state protections such as State and National Parks, Wildlife Refuges, and military installations,  
459 have the largest average parcel sizes. However, this may be almost completely endogenous, as

460 such large protected parcels that are unlikely to be sold to private developers were the most  
461 likely to be designated as OPAs in the first place.

462

463 **Table 3. Areal extent (within study zone extending 2 km inland from coastline) and sample**  
464 **size of parcels in five development disincentive categories (from Table 1)**

Category	Area (ha)	Coverage of study area (%)	Parcels (count)	Average parcel size (ha)
Non-CoBRA area, unprotected (Type 1)	459,905	38	1,228,760	0.3
Non-CoBRA area, protected (Type 2)	195,473	16	110,886	1.8
OPA (Type 3)	244,823	20	9,196	26.6
CoBRA unit, unprotected (Type 4)	243,994	20	21,879	11.2
CoBRA unit, protected (Type 5)	76,769	6	14,831	5.2
Total	1,220,964	100	1,385,552	0.9

465

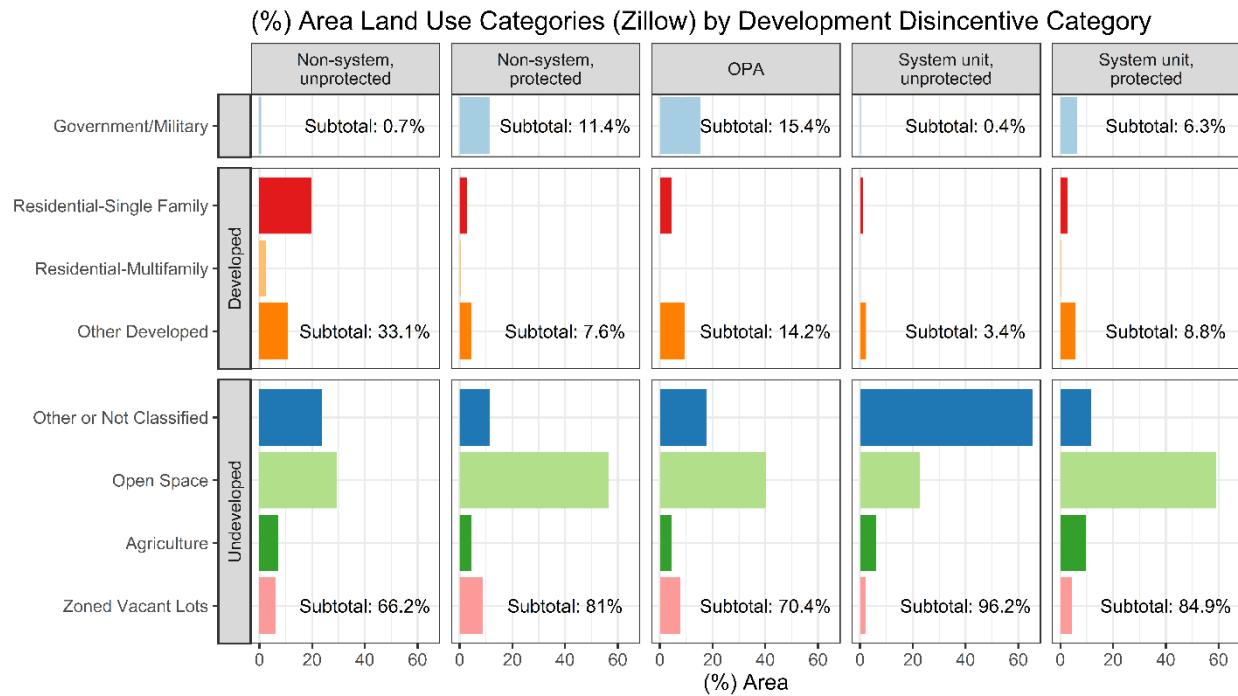
466 Parcels in protected CoBRA units are almost three-times larger, on average, than parcels  
467 in protected, non-CoBRA areas. This finding is consistent with federal subsidy withdrawal  
468 increasing development costs (H1) and thereby discouraging subdivision and development to a  
469 greater degree than local protections, such as park designations, do on their own (H2). When  
470 accounting for the land uses on these parcels (Fig 3), the interaction between CoBRA  
471 regulations and protection becomes clearer. When comparing protected, non-CoBRA areas with  
472 protected CoBRA units, most land in unprotected units is “Not Classified” or “Other,”  
473 indicating unparcelized and undeveloped land owned by states, counties, and municipalities, but  
474 not designated for any particular land use. In contrast, land in protected units is mostly  
475 designated as open space, such as parks. This could have important ramifications for future  
476 development patterns. It is possible that local protections (as opposed to large-scale state and

477 federal protections, typically represented in the OPA category) have been prompted by CoBRA  
478 designation itself (H2), particularly in areas that were otherwise attractive for development. This  
479 is an avenue for future study leveraging historical land ownership and protection records.

480

481

482 **Fig 3: Relative extents of different types of land cover and land use among development**  
 483 **disincentive categories. Urban land use is aggregated into *single-family residential*,**  
 484 ***multifamily residential*, and *other developed* (including unitary parcels of mobile home**  
 485 **parks, planned unit developments, and institutional residences). Undeveloped land use is**  
 486 **aggregated into *open space* (designated parks, wildlife areas, conservation areas etc.),**  
 487 ***agriculture* (any agricultural use), *zoned vacant lots* (referring to vacant lots that are**  
 488 **nevertheless zoned to permit residential, commercial, industrial, or institutional land**  
 489 **uses), and *other or not classified* (where parcels do not have designated land uses, they are**  
 490 **generally not formally parcelized by county tax assessors and represent undeveloped and**  
 491 **unused land). Government- and military-owned land may or may not have structures, but**  
 492 **are generally exempt from local government development restrictions as well as some**  
 493 **CoBRA subsidy restrictions.**



494

495            We present regression results (Fig 4; for full regression results see Supplementary Table  
496    2) with and without county fixed effects. The regressions without fixed effects show estimated  
497    average differences between each development disincentive category and unprotected, non-  
498    CoBRA areas across the entire sample. The regressions with county effects show the average of  
499    estimated differences between the categories *within each county*, thus accounting for differences  
500    between counties in the overall levels of each of the outcome metrics.

501

502            Among “developed” parcels (i.e., containing structures), unprotected CoBRA units  
503    (Type 4) show statistically ambiguous differences with unprotected, non-CoBRA areas (Type 1)  
504    in terms of percentage of land area covered by structures (H1; Fig 4a). Overall, unprotected  
505    CoBRA units experience slightly reduced development intensity (1% less parcel area covered  
506    by structures). However, when controlling for the county of observations (county fixed effects)  
507    CoBRA units experience slightly higher (1% more parcel area covered by structures)  
508    development intensity than non-CoBRA areas. This indicates that on average, parcels in  
509    unprotected CoBRA units with any development tend to have structures with smaller footprints  
510    relative to the parcel size than non-CoBRA areas, but this may have to do with correlations  
511    between the type of development that occurs in CoBRA units and overall development pressure  
512    and density in counties. When controlling for county (i.e., when comparing more spatially  
513    proximate CoBRA units and non-CoBRA areas), the relationship is reversed, indicating that in a  
514    given region, parcels in CoBRA units tend to have a larger proportion of their area covered by  
515    structures.

516

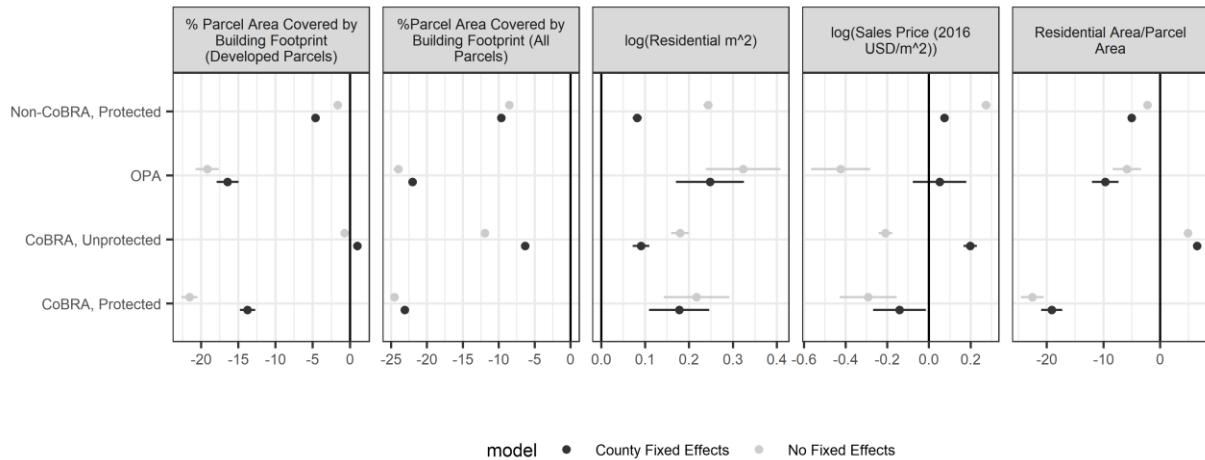
517                   Protection is associated with reduced development intensity on built-upon parcels in  
518    non-CoBRA areas by less than 5 percent, while protection in CoBRA units is associated with  
519    12-25 percent increases in intensity (H2; Fig 4b). This interaction between CoBRA and other  
520    protections is even stronger when considering residential area densities (Fig 4e), where  
521    protected CoBRA units (Type 5) have lower densities than any other category, while  
522    unprotected CoBRA units (Type 4) have the highest residential densities. Thus, in this respect,  
523    protection appears to strengthen the impact of CoBRA and is associated with a reduction in  
524    development intensity when it does occur (H2).

525

526                   This finding highlights a way in which federal policies, such as CoBRA, can be  
527    strengthened by the regulatory actions of other agencies. While CoBRA and other protections  
528    are independently associated with reductions in development and development intensity, when  
529    parcels have both types of policies applied, they experience even lower development intensity  
530    on average. That is, localities wishing to limit development in coastal barriers may find more  
531    success applying policy tools such as zoning and limits on infrastructure in CoBRA areas than  
532    non-CoBRA areas.

533

534 **Fig 4: Regression results. Dependent variables: (a) The percentage of parcel covered by**  
 535 **structure footprints, among only parcels with structures. (b) The percentage of parcel**  
 536 **covered by structure footprints, among all parcels. (c) The natural logarithm of residential**  
 537 **area (sq. m.) among parcels with residential land uses. (d) The natural logarithm of the**  
 538 **most recent inflation-adjusted sales price per square meter for residential parcels. (e) The**  
 539 **residential living area divided by the parcel area for residential parcels. Parcels are units**  
 540 **of analysis. The base category is *non-CoBRA, unprotected* areas (Type 1). Dots represent**  
 541 **point estimates and error bars indicate 95% confidence intervals. The x-axis is the effect**  
 542 **size (i.e., the average difference between parcels in the indicated category from parcels in**  
 543 **the base category). County fixed effects refer to regressions that use dummy variables to**  
 544 **control for the county in which parcels are located.**



545  
 546        However, CoBRA units and all protected areas experience larger average house sizes  
 547        ( $\log[m^2]$ ; Fig 4c). Moreover, controlling for individual counties (fixed effects), CoBRA unit  
 548        designation is associated with significantly higher property sales prices (Fig 4d). Thus, while  
 549        residential development in CoBRA units is less common than in non-CoBRA areas, the  
 550        development that does occur tends to be of larger, more expensive houses, which suggests luxury

551 effects (H3). This is consistent with the literature on the impact of parks and natural areas on  
552 property values, wherein such amenities are valued by consumers, and this value is expressed in  
553 sales prices<sup>51</sup>. We speculate that CoBRA might affect property values and development by  
554 providing large natural amenities with relatively low development intensity. It is also possible  
555 that, by restricting NFIP eligibility, any development that occurred in CoBRA units was  
556 necessarily initiated by those who could afford alternative insurance coverage, and that the  
557 income or wealth required to do so is correlated with willingness and ability to pay for larger  
558 and/or more expensive properties.

559

560 When controlling for protected status and system designation across all parcels in our  
561 study area, unprotected, non-CoBRA areas (Type 1) experience higher development intensities  
562 (% parcel covered by built structures) than unprotected CoBRA units (Type 4; H1; Fig 4b).  
563 Protected parcels in non-CoBRA areas experience a similar decrease in development intensity as  
564 unprotected parcels in CoBRA units. OPAs and protected CoBRA units are developed much less  
565 intensively than all other categories (H2), although much of this effect is likely due to the  
566 endogenous designation of CoBRA units in previously undeveloped areas.

567

## 568 Conclusion

569 Our results suggest strong relationships between CoBRA designation and resulting  
570 development density and land use. However, these results should not be interpreted causally due  
571 to the endogeneity with which CoBRA units were drawn around undeveloped areas. Even so,  
572 CoBRA designation is associated with lower development density, higher proportions of vacant

573 land, and larger average house size relative to non-CoBRA areas. This confirms much of our first  
574 hypothesis, H1: CoBRA is associated with lower development rates.

575

576 Moreover, the differences in house size, development propensity, and house sales prices  
577 (when controlling for the county) within CoBRA relative to unprotected areas outside CoBRA  
578 appear to be indistinguishable from the differences observed as a result of independent  
579 development restrictions initiated by other federal agencies and non-federal actors in areas such  
580 as parks, wildlife refuges, or conservation areas. This confirms parts of our second hypothesis  
581 (H2: CoBRA interacts with protected areas), and even suggests that CoBRA designation appears  
582 to have similar outcomes as designation as a protected area. Moreover, we provide evidence that  
583 CoBRA and other protections applied together may reduce development more than either alone.

584

585 While CoBRA designation shifts infrastructure costs to the private sector, our finding that  
586 protection and CoBRA are associated with equally expensive homes, suggests that CoBRA may  
587 create a strong seclusion effect that incentivizes luxury development patterns representing  
588 substantial property risk in coastal barriers.<sup>39</sup> However, our county fixed effects models  
589 demonstrate that this effect – which we suggested in our third hypothesis (H3: CoBRA creates a  
590 luxury effect for developed parcels) – may be mitigated at the community level. This regionally-  
591 dependent behavior suggests that the luxury effect may be mitigated by direct development  
592 restrictions, highlighting the potential importance of state and local land use policy in enabling,  
593 complementing, or counteracting federal policy goals.

594

595        Within the same county, there does not appear to be a direct relationship between the  
596 extent of development in CoBRA units and non-CoBRA areas. Counties with high development  
597 in CoBRA units do not necessarily have high non-CoBRA development rates, and many highly  
598 developed counties have little to no development in CoBRA units. This suggests that the primary  
599 determinant of development in CoBRA units is not scarcity of developable land in non-CoBRA  
600 areas. One possible explanation is that more complex spatial and political relationships are at  
601 play, rather than simply the spillover effects of our fourth hypothesis (H4; That is, in areas with  
602 high development pressure, development will eventually spill into CoBRA units).

603

604        In lieu of a direct spillover effect, we speculate that high development rates in CoBRA  
605 units could instead be the result of local or state development policies or subsidy substitutions.  
606 To determine this exact relationship, future work should consider the timing and spatial  
607 dependencies of development and policy within and around CoBRA units. This same work  
608 should consider the roles of changing state-level policies as well.

609

610        Is CoBRA achieving its statutory objective of reducing development in designated  
611 coastal barrier areas? Our results suggest that CoBRA has been successful in decreasing  
612 development rates and the total amount of development – the vast majority of CoBRA units  
613 remain undeveloped. Likewise, independent protection of coastal barriers has also been effective.  
614 However, CoBRA designation and other forms of protection appear to interact in preventing  
615 development, decreasing land values, and development densities. The particular regulatory  
616 mechanisms that may be complementary of, or offsetting to, CoBRA need to be investigated  
617 more fully with studies tracing local policies and development over time.

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624

625 **Author Contributions**

626 T.K.B., N.K., and D.S. conceptualized the research objectives and questions. K.O., N.K., and  
627 T.K.B. contributed to the research design. N.K., K.O. and J.B. collected and prepared data for  
628 analysis. K.O. led data analysis with input from all authors. K.O., T.K.B. and N.K. jointly wrote  
629 the manuscript with contributions from all authors.

630

631 **Competing Interests**

632 The authors have declared that no competing interests exist.

633

634 **References**

635

- 636 1. Arkema, K. K. *et al.* Coastal habitats shield people and property from sea-level rise and  
637 storms. *Nat. Clim. Change* **3**, 913 (2013).
- 638 2. Glavovic, B. C. & Smith, and G. P. *Adapting to Climate Change: Lessons from Natural  
639 Hazards Planning*. (Springer Science & Business, 2014).

640 3. Burby, R. J. *et al.* Unleashing the power of planning to create disaster-resistant communities.  
641 *J. Am. Plann. Assoc.* **65**, 247–258 (1999).

642 4. Beatley, T. & and Anna Schwab, D. B. *An Introduction to Coastal Zone Management*.  
643 (Island Press, 2002).

644 5. Gillis, J. & Barringer, F. As Coasts Rebuild and U.S. Pays, Repeatedly, the Critics ask Why.  
645 *N. Y. Times Online Accessed On* **8**, (2012).

646 6. Bagstad, K. & and John D'Agostino, K. S. Taxes, subsidies and insurance as drivers of U.S.  
647 coastal development. *Ecol. Econ.* **63**, 285–298 (2007).

648 7. Burby, R. Hurricane Katrina and the Paradoxes of Government Disaster Policy: Bringing  
649 About Wise Governmental Decisions for Hazardous Areas. *Ann. Am. Acad. Pol. Soc. Sci.*  
650 **604**, 171–191 (2006).

651 8. Leichenko, R. & Thomas, A. Coastal Cities and Regions in a Changing Climate: Economic  
652 Impacts, Risks and Vulnerabilities. *Geogr. Compass* **6**, 327–339 (2012).

653 9. Berke, P. & and Ward Lyles, G. S. Planning for Resiliency: An Evaluation of Coastal State  
654 Hazard Mitigation Plans. *Nat. Hazards Rev.* **2**, (2012).

655 10. *Coastal Barrier Resources Act.* 16 vol. 3501 et seq. (1982).

656 11. U.S. Fish and Wildlife Service. Coastal Barrier Resources System.  
657 <https://www.fws.gov/CBRA/>.

658 12. Knaap, G. J. The Price Effects of Urban Growth Boundaries in Metropolitan Portland,  
659 Oregon. *Land Econ.* **61**, 26–35 (1985).

660 13. Cunningham, C. R. Growth Controls, Real Options, and Land Development. *Rev. Econ. Stat.*  
661 **89**, 343–58 (2007).

662 14. Ding, C., Knaap, G. J. & Hopkins, L. D. Managing urban growth with urban growth  
663 boundaries: A theoretical analysis. *J. Urban Econ.* **46**, 53–68 (1999).

664 15. Pressman, N. & Wildavsky, A. *Implementation*. (University of California Press, 1973).

665 16. Hopkins, L. *Urban Development: The logic of making plans*. (Island Press, 2001).

666 17. Finn, D., D, H. L. & Wempe, and M. The Information System of Plans Approach: Using  
667 and Making Plans for Landscape Protection. *Landsc. Urban Plan.* **81**, 132–45 (2007).

668 18. Kaza, N. & Hopkins, and L. In What Circumstances Should Plans Be Public? *J. Plan. Educ.*  
669 *Res.* **28**, 491–502 (2009).

670 19. *Coastal Barrier Improvement Act.* 16 vol. 3503 (1990).

671 20. Horn, D. P. & Webel, B. *Introduction to the National Flood Insurance Program (NFIP)*. 31  
672 <https://fas.org/sgp/crs/homesec/R44593.pdf>.

673 21. Federal Insurance and Mitigation Administration. Fact Sheet Community Rating System.  
674 (2017).

675 22. Salvesen, D. The coastal barrier resources act: Has it discouraged coastal development?  
676 *Coast. Manag.* **33**, 181–195 (2005).

677 23. US Fish and Wildlife Service. Historical Changes to the Coastal Barrier Resources Act.  
678 <https://www.fws.gov/cbra/Historical-Changes-to-CBRA.html>.

679 24. Croft, B. T. & Boyd, A. FEMA strikes down second appeal on beach nourishment. 13–14  
680 (2013).

681 25. Millemann, B. A. *The Coastal Barrier Resources Act: Accomplishments, Challenges and*  
682 *Future Opportunities*. (Natural Resources Defense Council, 2010).

683 26. Jones, E. & Stolzenberg, and W. *Building in the Coastal Barrier Resources System*.  
684 (National Wildlife Federation, 1990).

685 27. Crawford, T. W., Marcucci, D. J. & Bennett, A. Impacts of residential development on  
686 vegetation cover for a remote coastal barrier in the Outer Banks of North Carolina, USA. *J.*  
687 *Coast. Conserv.* **17**, 431–443 (2013).

688 28. Pilkey, O. H. & Neal, W. J. North Topsail Beach, North Carolina: A model for maximizing  
689 coastal hazard vulnerability. *Am. Most Vulnerable Coast. Communities Geol. Soc. Am. Spec.*  
690 *Pap.* **460**, 73–90 (2009).

691 29. Dempsey, J. A. & Plantinga, A. J. How well do urban growth boundaries contain  
692 development? Results for Oregon using a difference-in-difference estimator. *Reg. Sci. Urban*  
693 *Econ.* **43**, 996–1007 (2013).

694 30. Weitz, J. & Moore, T. Development inside urban growth boundaries: Oregon's empirical  
695 evidence of contiguous urban form. *J. Am. Plann. Assoc.* **64**, 424–440 (1998).

696 31. Bengston, D. N., Fletcher, J. O. & Nelson, K. C. Public policies for managing urban growth  
697 and protecting open space: policy instruments and lessons learned in the United States.  
698 *Landsc. Urban Plan.* **69**, 271–286 (2004).

699 32. Dawkins, C. J. & Nelson, and A. C. Urban Containment Policies and Housing Prices: An  
700 International Comparison with Implications for Future Research. *Land Use Policy* **19**, 1–12  
701 (2002).

702 33. Brueckner, J. K. Growth Controls and Land Values in an Open City. *Land Econ.* **66**, 237–  
703 248 (1990).

704 34. Miller, T. I. Must growth restrictions eliminate moderate-priced housing? *J. Am. Plann.*  
705 *Assoc.* **52**, 319–325 (1986).

706 35. Nelson, A. C. Smart growth - central city vitality and higher quality of life. in (ed. Wachter,  
707 S.) (US Department of Housing and Urban Development, 2000).

708 36. Troy, P. N. Environmental stress and urban policy. in (eds. Jenks, M., Burton, E. &  
709 Williams, K.) (Chapman & Hall, 1996).

710 37. Knaap, G. J. The urban growth boundary in Metropolitan Portland, Oregon: Research,  
711 rhetoric, and reality. *PAS Memo No.*, (2001).

712 38. Pendall, R., Martin, J. and F. & W. Holding the line: Urban containment. in *the United States*  
713 (Institution, 2002).

714 39. William C. Garntner, Daniel E. Chappelle & T.C. Girard. The Influence of Natural  
715 Resources Characteristics on Property Value: A Case Study. *J. Travel Res.* **35**, 64–71 (1996).

716 40. Crossett, K., Ache, B., Pacheco, P. & Haber, K. National coastal population report,  
717 population trends from 1970 to 2020. *NOAA State Coast Rep. Ser. US Dep. Commer. Wash.*  
718 (2013).

719 41. U.S. Fish and Wildlife Service. Digital CBRS Boundaries. *Coastal Barrier Resources*  
720 System <https://www.fws.gov/cbra/maps/boundaries.html> (2018).

721 42. U.S. Geological Survey. Protected Areas Database of the U.S. (PAD-US). *National Gap*  
722 *Analysis Project (GAP) | Protected Areas Data Portal* <https://gapanalysis.usgs.gov/padus/>  
723 (2016).

724 43. Boundary Solutions, Inc. National Parcelmap Data Portal. *National Parcel Layer Content*  
725 *Service Provider* [www.boundarysolutions.com](http://www.boundarysolutions.com) (2018).

726 44. Zillow Group, Inc. ZTRAX: Zillow Transaction and Assessor Dataset, 2017-Q4.  
727 <http://zillow.com/ztrax> (2017).

728 45. Pebesma, E. Simple Features for R: Standardized Support for Spatial Vector Data. *R J.*  
729 (2018).

730 46. Microsoft. USBuildingFootprints. *Github*  
731 <https://github.com/Microsoft/USBuildingFootprints>.

732 47. Dannenberg, M. P., Hakkenberg, C. R. & Song, C. Consistent Classification of Landsat Time  
733 Series with an Improved Automatic Adaptive Signature Generalization Algorithm. *Remote*  
734 *Sens.* **8**, (2016).

735 48. Ward Jr, J. H. Hierarchical grouping to optimize an objective function. *J. Am. Stat. Assoc.*  
736 **58**, 236–244 (1963).

737 49. R Development Core Team. *R: A Language and Environment for Statistical Computing*.  
738 (2017).

739 50. Onda, Kyle, Branham, Jordan, BenDor, Todd K. & Kaza, Nikhil. Replication Data for: Does  
740 Removal of Federal Subsidies Discourage Urban Development? An Evaluation of the US  
741 Coastal Barrier Resources Act. *UNC Dataverse V1* (2020)  
742 doi:<https://doi.org/10.15139/S3/9KGNJY>.

743 51. John Crompton. The impact of parks on property values: A review of the empirical evidence.  
744 *J. Leis. Res.* **33**, 1–31 (2001).

745

## 746 Supplementary Table 1: Parcel characteristics retrieved from ZTRAX

Variable	Notes
AssessorParcelNumber	ID key used to match ZTRAX data to parcel polygons from NPDP
PropertyLandUseStndCode	An alphanumeric land use code corresponding to a more detailed land use description
YearBuilt	The year the structure (for which multiple may exist for one parcel) was constructed
SalesPriceAmount	The most recent sales price
RecordingDate	The date the most recent sale was recorded at the applicable county office. Sales may be recorded months after the actual transfer takes place, but the field for the actual sale date was completely missing for parcels in our study area.
BuildingAreaSqFt	The square footage of the structure as considered for real estate transactions. Generally “finished” square footage.

748 Supplementary Table 2: Regression results. Each dependent variable has two regression models, one without (odd numbered) and one  
 749 with (even numbered) county fixed effects. Coefficients represent mean differences in the dependent variable (columns) between  
 750 development disincentive category (rows) and base category of non-CoBRA, unprotected land (Type 1). Standard errors shown below  
 751 coefficients in parentheses. \* p<0.1, \*\* p<0.05, \*\*\*p<0.01

752

Structure footprint/parcel area (%) [parcels with buildings only]		Structure footprint/parcel area (%) [all parcels]		log(Residential area) (m <sup>2</sup> )		Residential area / parcel area (%)		log(Sales price (2016 USD)/residential area (m <sup>2</sup> )		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(11)	
County fixed effects?	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Non-CoBRA, protected (Type 2)	-1.666*** (0.11)	-4.663*** (0.11)	-8.542*** (0.09)	-9.672*** (0.09)	0.243*** (0.01)	0.082*** (0.01)	-2.253*** (0.13)	-5.042*** (0.13)	0.274*** (0.01)	0.074*** (0.01)
OPA (Type 3)	-19.184*** (0.79)	-16.442*** (0.75)	-23.997*** (0.33)	-21.997*** (0.31)	0.323*** (0.04)	0.248*** (0.04)	-5.861*** (1.27)	-9.692*** (1.19)	-0.425*** (0.07)	0.051 (0.07)
CoBRA unit, unprotected (Type 4)	-0.729*** (0.26)	0.963*** (0.25)	-11.944*** (0.19)	-6.352*** (0.18)	0.180*** (0.01)	0.091*** (0.01)	4.924*** (0.29)	6.538*** (0.28)	-0.209*** (0.02)	0.198*** (0.02)
CoBRA unit, protected (Type 5)	-21.551*** (0.55)	-13.754*** (0.53)	-24.518*** (0.22)	-23.082*** (0.21)	0.217*** (0.04)	0.177*** (0.04)	-22.563*** (1.02)	-19.139*** (0.94)	-0.292*** (0.07)	-0.141** (0.06)
Intercept	31.581*** (0.02)	18.419*** (0.11)	25.9*** (0.02)	14.234*** (0.10)	7.548*** (0.00)	7.422*** (0.00)	33.103*** (0.02)	18.884*** (0.12)	4.937*** (0.00)	5.044*** (0.01)
Observations	1,121,063	1,121,063	1,406,187	1,406,187	587,586	587,586	909,381	909,381	352,385	352,385
Adjusted R <sup>2</sup>	0.002	0.158	0.021	0.206	0.004	0.185	0.001	0.179	0.002	0.188
F Statistic	591***	2,799***	7,534***	4,606***	617***	2,783***	278***	2,825***	217***	2,210***

753

754      Supplementary Table 3: Hierarchical Linear Regression results. Coefficients represent mean differences in the dependent variable  
 755      (columns) between development disincentive category (rows) and base category of non-CoBRA, unprotected land (Type 1). Standard  
 756      errors shown below coefficients in parentheses. \* p<0.1, \*\* p<0.05, \*\*\*p<0.01

<i>Dependent variable:</i>					
	Structure footprint/parcel area (%) [parcels with buildings only] (1)	Structure footprint/parcel area (%) [all parcels] (2)	log(Residential area) (m <sup>2</sup> ) (3)	Residential area / parcel area (%) (4)	log(Sales price (2016 USD)/residential area (m <sup>2</sup> ) (5)
Non-CoBRA, protected (Type 2)	-4.653***  (0.110)	-9.667***  (0.089)	0.082***  (0.005)	-5.034***  (0.126)	0.074***  (0.010)
OPA (Type 3)	-16.494***  (0.749)	-22.004***  (0.304)	0.248***  (0.039)	-9.716***  (1.192)	0.051  (0.065)
CoBRA unit, unprotected (Type 4)	0.948***  (0.252)	-6.362***  (0.179)	0.091***  (0.010)	6.537***  (0.278)	0.198***  (0.016)
CoBRA unit, protected (Type 5)	-13.756***  (0.526)	-23.072***  (0.213)	0.177***  (0.035)	-19.124***  (0.943)	-0.143**  (0.064)
Constant	21.045***  (3.625)	15.146***  (3.086)	5.135***  (0.117)	22.780***  (3.502)	7.184***  (0.101)
Observations	1,121,063	1,406,187	587,586	909,381	352,385

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