The Effects of the BP Deepwater Horizon Oil Spill on Housing Markets*

Javier Cano-Urbina[†], Christopher M. Clapp[†], and Kevin Willardsen[‡]

January 29, 2018

[Click for Most Recent Version]

Abstract

When the *Deepwater Horizon* oil rig exploded in 2010, it resulted in the largest off-shore oil spill in United States history. Economic theory dictates that the oil damage and restitution payments that resulted from the spill should be capitalized into property values. To measure the extent of this capitalization, we create a novel dataset by linking surveys of the location and severity of oil observed along over 4,300 miles of the Gulf Coast to measures of local housing market outcomes. We then perform hedonic-style analysis to determine the net effects of the spill on affected real estate markets. In doing so, we provide the first plausibly causal estimates of the effect of the spill on affected housing markets throughout the Gulf region. Identification comes from a triple-difference framework that exploits the random nature of both the spill and the spatial distribution of oil that affected coastal communities as well as controlling for the confounding effects of the housing market crash. Results suggest that on net, the BP oil spill caused a significant decline in the home prices of between four and eight percent that persisted until at least 2015. This implies housing markets capitalized \$3.8 billion to \$5.0 billion in spill damage net of clean-up and restitution. These results are robust to numerous alternative definitions of treatment and control groups.

*For valuable comments, we thank Kelly Pace, Will Doerner, Carl Kitchens, Patrick Smith, John List, and participants at the FSU-UF Critical Issues in Real Estate Symposium, FSU Quant Workshop, WSU Applied Economics Workshop, 12th Meeting of the Urban Economics Association, and University of Chicago Experimental Lunch Seminar. All errors are our own.

[†]Florida State University

[‡]Wright State University

Keywords: Environmental Damage, Oil Spill, Housing Markets, Capitalization, Hedonic Analysis, Triple-Difference Estimator
JEL Codes: Q40, Q51, Q53, R11, R31

1 Introduction

In April of 2010, Transocean's *Deepwater Horizon* oil drilling rig operating in the Gulf of Mexico exploded and subsequently sank. In addition to 11 crewmen losing their lives and numerous other rig operators sustaining injuries, the explosion left British Petroleum's (BP) Macondo well severely damaged.[1] An estimated 134 million gallons of oil spilled into the Gulf of Mexico over the next 87 days, and an additional 1.4 million gallons of chemical dispersant were spread on the resulting oil slick (Smithsonian Ocean Portal Team, 2016).[2] The BP *Deepwater Horizon* oil spill is the largest off-shore oil spill in United States history (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016).[3] It resulted in immense environmental damage throughout the Gulf; reduced aesthetic amenities and the general livability of the area; harmed coastal economies reliant on the Gulf for fishing, recreation, and tourism; and potentially affected the health of citizens in five different states in ways that are not yet fully known.[4] Bishop et al. (2017) estimate that the total willingness to pay to avoid a similar disaster exceeds $17 billion.

In contrast to the negative effects of the spill, BP spent an estimated $44 billion on cleanup and legal costs, and, in late 2015, reached a $20.8 billion dollar agreement to settle all federal, Gulf Coastal state, and local government claims (Gilbert and Kent, 2015; Barrett, 2015).[5] BP's efforts to restore the natural habitats and compensate the citizens they harmed mitigated the effects of the spill and may have resulted in improvements to some community

[1]For a detailed description of the incident, see Deepwater Horizon Natural Resource Damage Assessment Trustees (2016).

[2]For a visual representation of the timing of events related to the spill, see Appendix A.1. For a more detailed account of the spill and subsequent policy response, see Aldy (2011).

[3]The incident is also referred to as the BP oil spill, the *Deepwater Horizon* oil spill and the Gulf oil spill. We use these names interchangeably throughout the text.

[4]The Gulf Coastal states are Alabama, Florida, Louisiana, Mississippi, and Texas. Winkler and Gordon (2013) posit the existence of health effects, but provide no direct evidence. We know of no study that establishes a link between the BP oil spill and adverse health outcomes, likely due to the long-run nature of such effects and the methodological difficulties in credibly identifying such a connection. That the *Deepwater Horizon* Oil Spill Medical Benefits Settlement provides payments to eligible residents and clean-up workers for certain medical conditions suggests that such a relationship exists. See http://www.deepwaterhorizonsettlements.com for more details.

[5]This is in addition to a $4 billion penalty to settle federal criminal charges and additional civil suits, many of which are still pending.

amenities in the affected areas.

While these effects cannot be quantified directly, economic theory dictates that local amenities and dis-amenities (either real or expected) are capitalized into property values (Rosen, 1974). We theorize that the BP oil spill diminished the demand for affected properties through the previously listed channels, but that the value of some homes in the area may have actually increased along some dimensions as a result of restitution efforts. To determine the net effect of the spill, we use a measure of annual housing market appreciation based on single-family home sales by ZIP Code developed by Bogin et al. (2016) and survey data on the location and severity of oil observed along over 4,300 miles of the Gulf Coast from the National Oceanic and Atmospheric Administration's (NOAA) Environmental Response Management Application (ERMA) (MC-252 SCAT Program, 2014).[6] We use Geographic Information System (GIS) techniques to spatially merge these datasets, then perform hedonic-style analysis in differences-in-differences (DD) and triple-difference (DDD) frameworks to determine the causal effects of oil from the spill capitalized by real estate markets along the Gulf Coast.

Hedonic models have long been used to quantify the effects of non-market amenities ranging from the negative effects of small-scale hazardous waste sites on property values (Ihlanfeldt and Taylor, 2004) to the premiums associated with high functioning school districts (Chiodo et al., 2010).[7] Although these models are popular, Freeman III et al. (1993) and Deaton and Hoehn (2004) point out the difficulties of separately identifying the variable of interest from confounding factors. Recent work has used DD or DDD frameworks to identify, for instance, the effects of rising sea levels (Ortega and Taṣpinar, 2016), the impact of the redevelopment of contaminated lands (Haninger et al., 2014), and the effects of hydraulic fracturing (Muehlenbachs et al., 2015) with hedonic models. It is the tradition of these works that motivates our identification strategy.

Descriptive DD analyses suggest that the net effect of the oil spill was mostly limited to markets close to the coast. Additionally, the housing market bubble and correction, subprime mortgage crisis, and subsequent Great Recession (hereafter, we refer to these collective events as the housing market crash) confound estimation of the effects of the spill. Our descriptive analysis raises two important points and motivates our main specifications.

[6] ERMA was created by NOAA's Office of Response and Restoration and the University of New Hampshire's Coastal Response Research Center. The U.S. Environmental Protection Agency (EPA) also contributed to the project.

[7] For an early, but in depth review of the uses of and issues with hedonic analysis, see Freeman III (1979). For a survey of the literature, see Farber (1998).

In particular, it suggests the need for an empirical model that (i) accounts for the potentially localized effect of the oil spill without ignoring regional effects and (ii) addresses differences in the housing market crash experiences of coastal and inland markets not fully captured by available controls. These insights motivate a DDD analysis that accounts for differences between treated and unaffected communities, markets before and after the spill, and inland and coastal communities. We find strong evidence that suggests that this DDD specification effectively controls for changes in regional and macroeconomic conditions caused by the housing market crash.

DDD estimates show that the net effect of the oil spill caused a statistically significant decrease in home prices of 4 to 8 percent that persisted for at least five years. Back-of-the-envelope calculations indicate that the spill caused a minimum of $3.8 billion to $5.0 billion in damages that were capitalized by housing markets. Placebo and permutation tests support our findings, and our estimates are very robust to variations in the definition of coastal and inland areas. They are strongest in housing markets close to the coast and show a decaying effect of the spill as the treatment group expands inland, suggesting an intuitive, negative gradient in the effect of the oil spill. Additionally, we provide evidence consistent with more intense oil damage having a more negative effect on housing values, but we are unable to show conclusively that this is the case.

Generally, our work can be placed in a broad literature that uses hedonic analysis to estimate the effects of externalities on housing markets. More narrowly, we make at least four contributions to the existing literature on the BP oil spill itself. First, while researchers have studied the impact of the BP oil spill on local labor markets (Aldy, 2014), tourism (Whitehead et al., 2016), and advertising (Barrage et al., 2014), to the best of our knowledge, we are the first to plausibly estimate the effects of the spill on single-family housing markets across the entire Gulf Coastal region. Only Winkler and Gordon (2013) and Siegel et al. (2013) have studied the impact of the BP oil spill on housing markets in a systematic way. Both do so using condominiums and a very limited set of locations (the same coastal county in Alabama) in the short-run.[8] We cover a different set of residential properties in all five Gulf States, and our analysis spans a longer time period.[9] While both Winkler and Gordon (2013) and Siegel et al. (2013) find that the spill had negative effects similar in magnitude to our estimates, they also conclude that the effects of the spill were far more short-lived (on

[8]Winkler and Gordon (2013) analyze the period from January 2010 until February 2011. The Siegel et al. (2013) analysis covers the period from January 2009 through September 2011.

[9]Our outcome variable is a housing price index based on single-family unit transactions. Our analysis covers the years 2008-2016.

the order of three months) than our findings of effects that persist to 2015 indicate.

Second, and more importantly, unlike the pre versus post (single-difference) study methodologies used by Winkler and Gordon (2013) and Siegel et al. (2013), we use DDD specifications that allow us to compare changes in housing market outcomes in treated locations before and after the spill to changes in plausible control locations. As opposed to the previously cited before-after comparison analyses (that, by their nature, do not control for aggregate market effects), our empirical specification allows us to separately identify the effects of the spill from confounding housing market factors under plausible assumptions. Since our period of analysis coincides with the housing market crash, naive comparisons of home values in the pre- and post-spill periods that do not account for these changing market conditions against a reasonable benchmark are likely to misstate the true effect of the spill.

Third, while our research question is similar to those of Winkler and Gordon (2013) and Siegel et al. (2013), our empirical specification is most closely related to that of Aldy (2014)'s analysis of the net impacts of the spill on labor markets. We improve upon the DD specification used by Aldy (2014) by incorporating detailed information on the actual oil damage experienced by coastal communities. As opposed to considering all Gulf Coastal locations as receiving an equal treatment, we are able to define multiple treatments based on whether a locality actually had oil wash up on its shores and how proximate the community was to observed shore oiling. We estimate models based on these definitions of treated communities in addition to one analogous to Aldy (2014)'s definitions based on whether or not a jurisdiction is located in the NOAA defined coastal watershed.

Fourth, by using the ZIP Code/ZIP Code Tabulation Area (ZCTA) as our unit of observation, we use a finer level of geography than the counties and parishes (hereafter, collectively referred to as counties) used by Aldy (2014).[10] This allows us to better measure the outcomes of those affected by the spill by controlling for local housing market effects at the county level. These controls are particularly important given the concurrent and heterogeneous effects of the housing market crash during our period of analysis.

Section 2 discusses how we construct our estimation dataset. The following section details our empirical specification and presents our model estimates. Section 4 concludes.

[10] We acknowledge that Aldy (2014) makes use of higher frequency (quarterly) labor market data than we have access to for the housing market that allows him to separately identify the effects of the spill from the drilling moratorium. As discussed in Section 2.1, cell size concerns in the construction of our outcome variable limit us to annual analysis.

2 Data

Our data comes from two main sources. Our dependent variable is a ZIP Code-level house price index produced by the staff at the Federal Housing Finance Agency (FHFA). Our independent variables are constructed from geo-data on the location and intensity of oil damage along the coast made available through the ERMA Deepwater Gulf Response mapping tool.[11] We discuss each of these sources and how we spatially merge disparate geographies in the following subsections. Then we report the effects of a descriptive analysis based on the merged dataset.

2.1 FHFA House Price Index Data

We use data on home values in Gulf Coastal states to quantify the effects of the spill on housing markets. This home value data takes the form of a repeat-sales house price index (HPI) developed by Bogin et al. (2016) for the FHFA. The HPI represents the cumulative change in house prices in the 5-digit ZIP Code relative to a base year.[12] The authors produce the HPI for the years 1975-2016 using a FHFA proprietary database of single-family home mortgage transactions that contains information on all conventional and refinanced mortgages either guaranteed or acquired by Fannie Mae or Freddie Mac. In order to difference out unobserved household-level quality differences, the authors restrict their sample to homes that transact multiple times. They then calculate the index for each ZIP Code conditional on sufficient cell size requirements being met.[13]

Bogin et al. (2016) caution that cell count restrictions are particularly binding in earlier years and in low population areas with few housing transactions. As our analysis focuses on an event that occurred in 2010, near the end of their sample period, we are primarily concerned with the extent of their geographic coverage. Table 1 contains counts of ZIP Codes by the availability of HPI data for the Gulf States and Georgia in 2010. Overall, we have

[11] The house price index data are available from http://www.fhfa.gov/papers/wp1601.aspx, and the ERMA application can be accessed at https://gomex.erma.noaa.gov/erma.html.

[12] The base year is defined as the earliest year for which the HPI can be calculated for the given ZIP Code. We do not standardize to a common base year as this removes the ZIP Code from our sample whenever data for the chosen base year is missing. Instead, we include ZIP Code fixed effects in our analyses to account for differences in base years across ZIP Codes.

[13] Although the index is based on roughly 100 million transactions, there is a common "curse of dimensionality" trade-off along the temporal and spatial dimensions that means the FHFA index cannot be produced more frequently than annually at the ZIP Code level. Zillow produces a house price index at the 5-digit ZIP Code level that varies monthly, but because there are fewer potential cells per observation, coverage of the Gulf Coast is far less complete. For this reason, performing our analysis at the monthly level is not feasible. We trade spatial coverage for temporal frequency and choose the annual FHFA index for our analysis.

price index information for 57 percent of the ZIP Codes in the region. Florida has the best coverage at 81 percent, but Mississippi and Texas have price index information available for less than 50 percent of their ZIP Codes.

Table 1: Counts of ZCTAs by State and HPI Availability

	State						
	AL	FL	GA	LA	MS	TX	Total
HPI Available	362	797	480	271	159	907	2,976
HPI Missing	280	186	255	244	264	1,025	2,254
Total	642	983	735	515	423	1,932	5,230
Percent Available	56%	81%	65%	53%	38%	47%	57%

Note: The abbreviations in the table denote the Gulf States: AL=Alabama, FL=Florida, GA=Georgia, LA=Louisiana, MS=Mississippi, and TX=Texas.

These low coverage rates are a cause for concern for our analysis only if we do not have adequate coverage of the coastal ZIP Codes that form our treatment groups or the lack of HPI availability is the result of selection related to the spill. We provide evidence that neither is the case. To do so, as well as to provide a better sense of the spatial distribution of coverage (and ultimately, to merge our independent and dependent variables as discussed in the next section), we obtain information on the locations of the boundaries of the Census ZIP Code Tabulation Areas (ZCTAS) that correspond to ZIP Codes across the country using the 2010 Census TIGER/Line 5-Digit ZCTA boundary shapefiles.[14] ZCTAs are a Census geography that are a close approximation of actual postal ZIP Codes. They are created by identifying the primary ZIP Code within each Census block, then aggregating blocks with a common ZIP Code to form the ZCTA.[15] By linking the HPI ZIP Code level data to the ZCTA data, we can determine the spatial distribution of HPI information.[16]

[14]We obtain these shapefiles from The IPUMS National Historical Geographic Information System (NHGIS) (Manson et al. 2016). They are available at http://www.nhgis.org.

[15]See https://www.census.gov/geo/reference/zctas.html for additional details about this process. ZCTAs differ from actual ZIP Codes in two ways. First, because they are created from Census blocks, the boundaries of ZCTAs do not exactly match those of a ZIP Code. This may introduce measurement error into our analysis which would attenuate results. Second, since ZCTAs are based on Census blocks that are drawn to ensure population coverage, only populated areas are assigned to a ZCTA. This primarily affects "point" ZIP Codes such as those assigned to large businesses to facilitate mail sorting, but also affects uninhabited natural areas (http://mcdc.missouri.edu/allabout/zipcodes_2010supplement.shtml). As we are ultimately interested in linking ZCTAs to ZIP Code level residential transactions, this should not affect our analysis.

[16]While our price index information is incomplete, we have geographic information on the locations of almost all ZIP Codes in the FHFA data. Of the 2,521 ZIP Codes in the HPI in one of the Gulf States in 2010, we are able to match 2,519 (99.9%) to a ZCTA. The unmatched ZIP Codes appear to have been created by the U.S. Postal Service after the geo-data file was created (Census uses ZIP Codes as of January 1, 2010 when creating the file). None are near the coast.

Figure 1 maps the availability of price index information for the Gulf States and Georgia.[17] Dark blue shading indicates ZCTAs for which HPI information is available in the year 2010 (the graphic is similar for the other years in our analysis). Light blue indicates that there are insufficient transactions to calculate the HPI, and white spaces within the continental U.S. indicate locations where an insufficient number of people live for the Census to create a ZCTA.[18] The figure shows that although the coverage of the HPI is far from complete, missing HPI information is primarily an issue in the rural, inland parts of the states, particularly in West Texas. Urban and coastal jurisdictions with high population densities have relatively complete coverage. Together, this suggests that the low coverage rates in Table 1 are driven by a lack of housing transactions in sparsely populated locations as Bogin et al. (2016) suggest. While we acknowledge that our results should be interpreted as being conditional on the existence of a sufficiently robust housing market in the jurisdiction, we do not find evidence of incomplete coverage of the coast or selection due to the spill that would confound our estimation strategy.[19]

2.2 ERMA Oil Location Survey Data

In order to determine what communities were most directly impacted by oil from the spill, we use geo-data collected as part of the Natural Resource Damage Assessment (NRDA) and made publicly available via the ERMA website in the form of GIS shapefiles.[20] This spatial data contains the results of field surveys performed by 18 Shoreline Cleanup Assessment Technique (SCAT) teams operating simultaneously from May 2010 until April 2014. SCAT teams inspected the coastline from the panhandle of Florida through Louisiana multiple times, recording both the quantity of oil present and the exact location of each surveyed

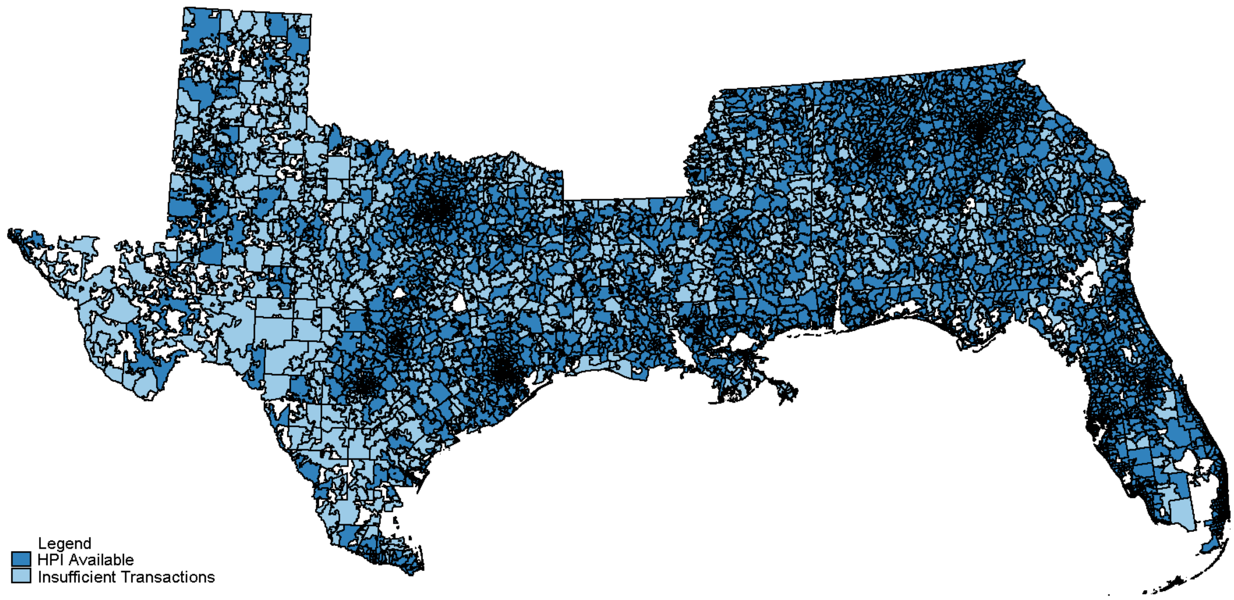
[17]In some specifications, we define treatment and control based on distance from the surveyed coast. In such cases, Georgia jurisdictions are included in the analysis.

[18]For instance, the large white areas in southern Florida are Lake Okeechobee and the Everglades.

[19]Bogin et al. (2016) also produce HPI data at the county level. The broader geographic scope of a county-level index ensures there are sufficient repeat-sales transactions in each jurisdiction such that cell count restrictions are not binding, and the county data provides complete coverage of the region. To further investigate the effects of incomplete coverage in our ZIP Code-level data, we reproduce our baseline set of analyses using this county-level data and results are qualitatively similar. This further supports our assertion that the potential sample bias introduced by using incomplete ZIP Code-level data is not of great concern. Hence, in order to use a finer unit of observation that we can more accurately match to observed oil damage, we proceed with analysis at the ZIP Code level. Results using the county-level data are available from the authors upon request.

[20]According to the NOAA website, the NRDA is "the legal process that federal agencies like NOAA, together with the states and Indian tribes, use to evaluate the impacts of oil spills, hazardous waste sites, and ship groundings on natural resources both along the nation's coast and throughout its interior" (http://oceanservice.noaa.gov/facts/nrda.html).

Figure 1: FHFA HPI Coverage by ZCTA, 2010



segment of the coast.[21] As not all coastal segments were surveyed multiple times, the data report the maximum oil damage that was observed along the segment at any point in time. This measure is coded as falling into one of nine different categories that represent bands of oil with similar characteristics. These categories, in increasing order of the intensity of the oil spill, are: (i) no oil, (ii) negligible tar balls, (iii) light tar balls, (iv) moderate tar balls, (v) heavy tar balls, (vi) very light oil, (vii) light oil, (viii) moderate oil, and (ix) heavy oil.

Table 2 represents the distribution of oil observed by the intensity of oil damage. The table lists the count of segments by the maximum oil observed in column (1), and column (2) lists the number of miles of coastline where the given level of oiling was observed. Columns (3) and (4) display the observed counts/mileages by category as a percent of the total segments/miles surveyed. Focusing on the latter two columns, Table 2 shows that of the 4,376.5 miles of coast that were surveyed, no oil was found 75 percent of the time. Some level of tar ball damage was observed along 3.3 percent of the surveyed coast, and some level of oil damage was observed along the remaining 21.7 percent of the coast. Figure 2 displays this information visually: the spatial distribution of oil observed is represented by the colored segments along the coast and the intensity of oil damage is presented using colors ranging from blue (no oil) to red (heavy oil).

The SCAT data does not contain any jurisdictional location information, but each ob-

[21]SCAT teams surveyed 4,300 unique miles of coast, but performed 28,000 miles of inspections with repeat surveys. For a complete description of survey procedures, see MC-252 SCAT Program (2014).

Table 2: Distribution of Segments by Maximum Oil Observed

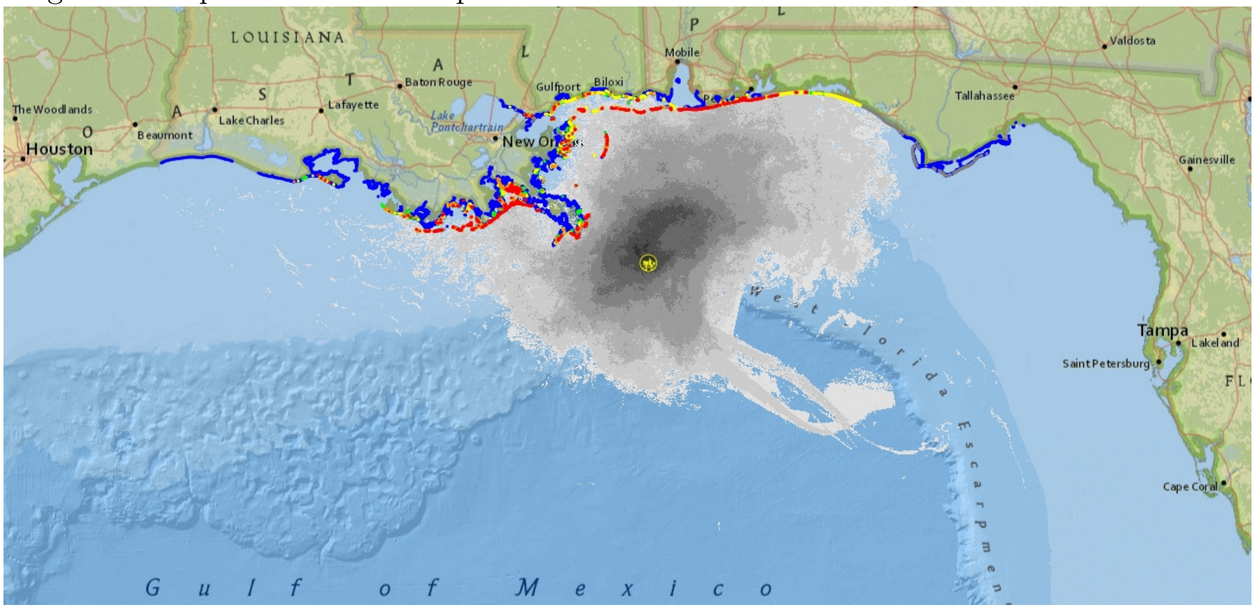
	(1) Number of Segments	(2) Miles of Segments	(3) Percentage of Segments (%)	(4) Percentage of Miles (%)
No Oil	5052.0	3281.1	53.9	75.0
Negl. Tar Balls	12.0	2.6	0.1	0.1
Light Tar Balls	471.0	116.4	5.0	2.7
Mod. Tar Balls	144.0	23.0	1.5	0.5
Heavy Tar Balls	12.0	1.9	0.1	0.0
Very Light Oil	591.0	197.9	6.3	4.5
Light Oil	1522.0	392.8	16.2	9.0
Moderate Oil	606.0	139.4	6.5	3.2
Heavy Oil	961.0	221.3	10.3	5.1
Total	9371.0	4376.5	100.0	100.0

servation contains the geographic coordinates of the given section of the coast. In contrast, observations in our house price index dataset vary geographically by ZIP Code (for each given year), but contain no other location information or coordinates. We match observations based on these two disparate geometries in two ways. First, we use GIS techniques to map the SCAT survey segments to the ZCTA they are contained in.[22] Since there are multiple surveyed segments in each coastal ZCTA, we use the maximum observed oiling in the ZCTA as our damage measure. Second, we calculate the distance to the nearest segment surveyed (both unconditionally and by oiling category) to allow effects to vary with both distance and intensity of damage. We are then able to merge the HPI data to the SCAT oil survey data by linking ZIP Codes to ZCTAs to create the dataset used for our analysis.

Table 3 displays the results of these matching algorithms at the ZIP Code level, conditional on the availability of HPI data in 2010. Column (1) reports the distribution of ZIP Codes by the category of maximum oil observed within the boundaries of the ZCTA. Due to the Census Bureau defining ZCTA boundaries based on where individuals live, not jurisdictional boundaries, we are only able to match segments to 40 ZIP Codes along the coast. Additionally, compared to Table 2, the distribution skews towards more oil damage (due to aggregating multiple segments per jurisdiction by taking the maximum observed damage). Given this imperfect matching, Columns (2) - (8) contain the count of ZCTAs matched to the given level of oil damage by distance to the closest segment within bands of five and ten miles. Compared to the first matching method, the distance distributions are relatively similar to the overall, segment level distribution reported in the previous table.

[22]Each observation in the SCAT data can be visualized as a line segment whereas the ZCTAs are polygons.

Figure 2: Map of the Gulf Oil Spill and the Locations of Oil Observed on the Gulf Coast



Source: Environmental Response Management Application (https://gomex.erma.noaa.gov/erma.html).

These distance calculations allow us to estimate models that define the treatment and/or control groups based on distance to the closest surveyed or affected coastal segment. As we increase the distance bands from 50 to 400 miles in Columns (4) - (8), we are able to match more ZCTAs to oil damage, and in the limit, we could assign all 2,976 ZCTAs in the region with HPI information available (as reported in Table 1) to oil damage. To inform reasonable cutoffs, Figure 3 is a histogram of the distance from each ZCTA's centroid to the nearest SCAT surveyed coastal segment (regardless of the category of damage observed, if any). The figure demonstrates two facts. First, there are a mass of ZCTAs close to the (surveyed) coastline due to the population density along the coast. Second, the majority of the density falls within 400 miles of the surveyed coast, with a first quartile distance of approximately 125 miles and a median distance of just over 210 miles.

We augment the data by adding indicators for NOAA definitions of Gulf Coastal counties used by Aldy (2014) to define additional, alternative treatment and control groups.[23] Additionally, similar to the way we spatially merge segments to ZCTAs, we merge the ZCTAs

[23]NOAA defines coastal counties for the entire United States as those that have 15 percent or more of their total land area in the coastal watershed or counties that make up 15 percent or more of a given coastal cataloging unit (drainage basin). See http://www.census.gov/geo/landview/lv6help/coastal_cty.pdf and https://coast.noaa.gov/htdata/SocioEconomic/NOAA_CoastalCountyDefinitions.pdf for more information.

Table 3: Count of ZIP Codes by Distance Measures and Maximum Oil Observed

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ZCTA	Closest Segment to ZCTA Distance (Miles)						
	Contains	≤5	≤10	≤50	≤100	≤150	≤200	≤400
No Oil	12	43	69	284	512	792	1228	2511
Negl. Tar Balls	0	0	0	0	0	0	0	0
Light Tar Balls	3	7	9	12	13	13	13	14
Mod. Tar Balls	2	2	2	5	10	10	10	10
Heavy Tar Balls	0	0	0	0	0	0	0	0
Very Light Oil	0	3	3	5	5	10	11	15
Light Oil	9	14	15	19	35	55	112	306
Moderate Oil	2	2	2	2	2	2	2	2
Heavy Oil	12	14	14	15	16	19	19	28
Total	40	85	114	342	593	901	1395	2886

Note: Column (1) reports the maximum oil damage observed by ZCTA. Not all the categories of oil damage were matched or found to be the maximum.

to counties and states based on the jurisdiction the ZCTA's centroid falls in to allow for additional controls at those levels.[24]

2.3 Descriptive Analysis

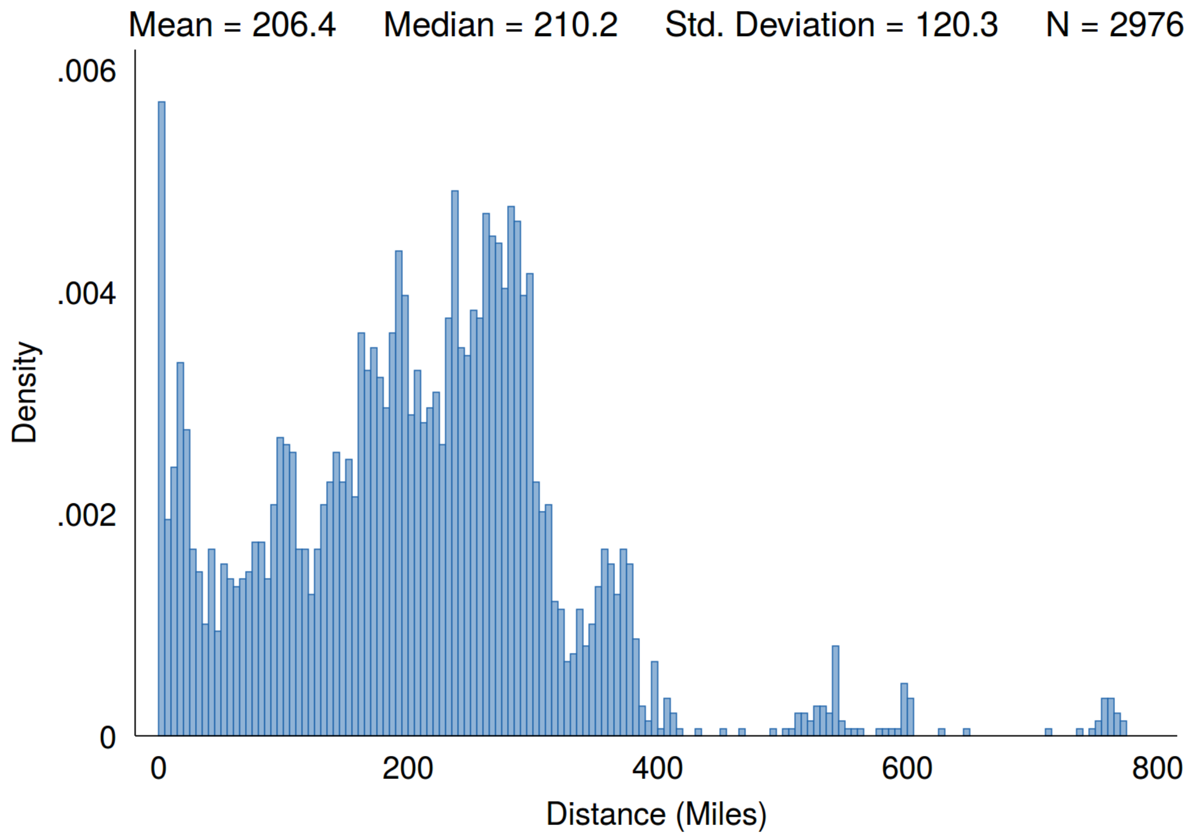
By geo-matching the HPI and oil spill data, we are able to visualize how Gulf Coastal housing markets evolved over time. In order to illustrate the effects of the spill, we define simple treatment and control groups by a ZIP Code's proximity to oil damage.[25] We restrict our sample to all ZIP Codes that are within 150 miles of coastal areas that were inspected by SCAT teams. Among this subset of ZIP Codes, we select into the treatment group those ZIP Codes within 100 miles of an inspected area where at least some level of oil (negligible tar balls or more) was observed, and assign the rest of the ZIP Codes in our sample to the control group.[26] As a result, our treatment group will include some ZIP Codes that are not

[24]We obtain county boundary information from the 2010 Census TIGER/Line County boundary shapefiles from NHGIS. We were unable to match 109 of the nation's 33,120 ZCTAs to a county using this method. This mainly occurred in coastal areas where NHGIS trimmed the county shapefile according to a different definition of the coastline than the ZCTA file. In order to assign these unmatched ZCTAs to a county, we use the Census Bureau's "2010 ZCTA to County Relationship File" (available at https://www.census.gov/geo/maps-data/data/zcta_rel_download.html). The relationship file provides a crosswalk between Census geographies, but does not ensure a unique match. ZCTAs that span multiple counties were assigned to the county that overlaps with the greatest percent of the ZCTA.

[25]To distinguish these groups from additional alternatives we define in Appendix A.3, we refer to this as our "Distance to Observed Oil" definition.

[26]These distance cutoffs are centered on the first quartile distance of approximately 125 miles.

Figure 3: Density of ZCTAs by Distance to Surveyed Coastline

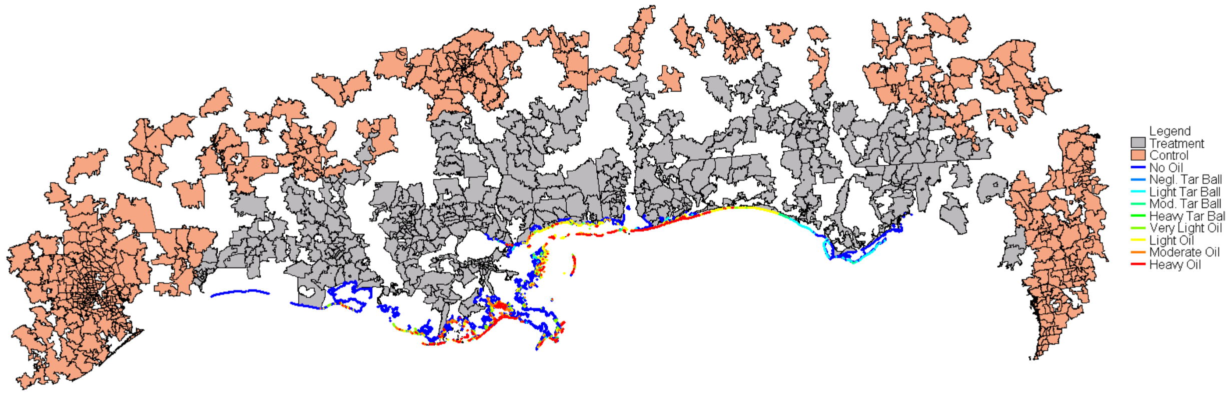


Note: Distance is calculated as the number of miles from the ZCTA to the closest point on the SCAT surveyed coastline. The histogram groups distances in five mile bins.

directly on the coast, but that are close to oil damaged segments of the coast. Similarly, our control group will contain ZIP Codes directly on the coast, but not close to any observed shoreline oil damage. Columns (5) and (6) of Table 3 present the count of ZIP Codes within each distance band by level of oil damage, and Figure 4 presents a map of the ZIP Codes in the treatment and control groups for this definition.

Figure 5 plots the unconditional average price index per year for single-family houses located in the treatment and control ZIP Codes from 2000 to 2016. Taken at face value, the trends in Figure 5 do not indicate that the spill had a pronounced effect on housing markets: the unconditional averages in both groups behave similarly after the oil spill in 2010. The figure illustrates the challenges we face in designing an appropriate estimator of the effects of the spill. The spill occurred in the midst of drastic changes to the economy due to the housing market crash. The confounding effects of the crash make it difficult to define

Figure 4: Treatment and Control Groups: Distance to Observed Oil



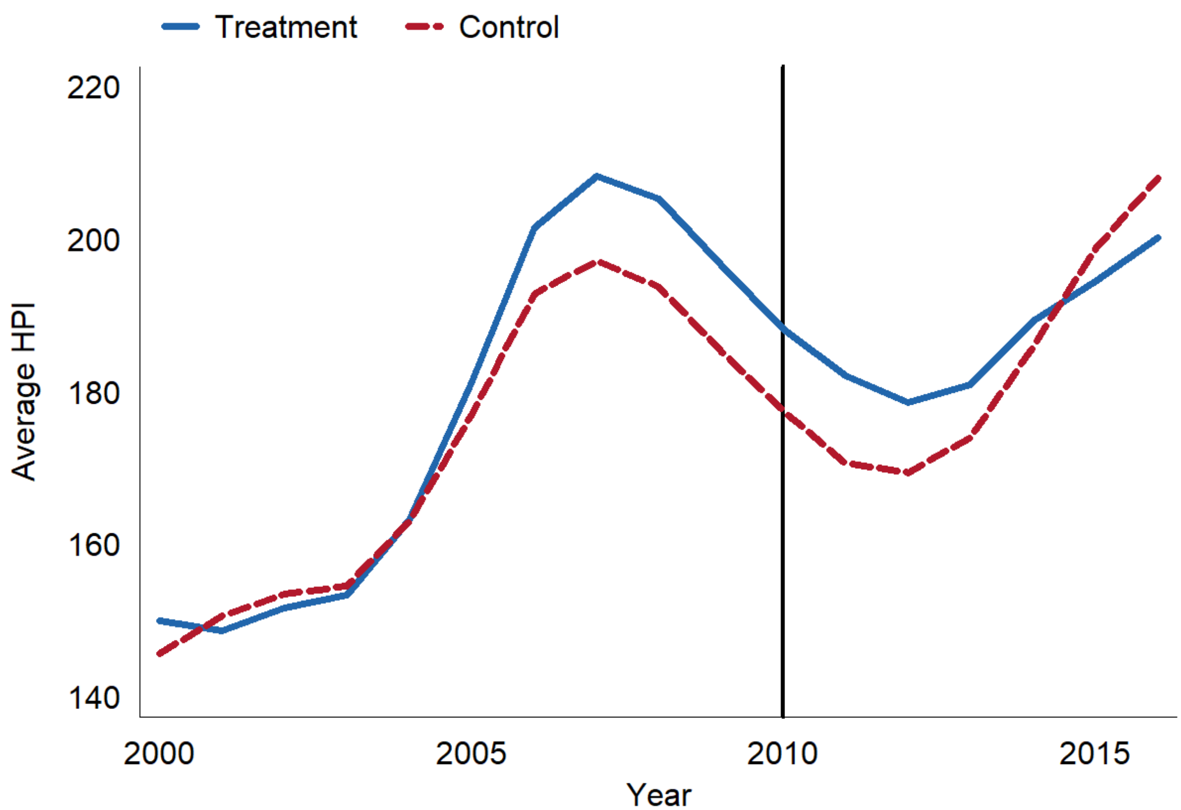
an appropriate control group in what is akin to a simple DD estimator because different Gulf Coastal housing markets had different housing market crash experiences. Markets in ZIP Codes in the treatment group saw higher prices on average than markets in the control groups during the housing boom and prior to the spill. We choose treatment and control definitions to provide the most comparable groups possible. In doing so, our broad treatment definition attenuates the effects of oil damage that are likely to be strongest near the coast. We outline a model that addresses these challenges to the identification of the effects of the spill in the next section.[27]

3 Empirical Methodology and Results

The descriptive analysis in the previous section shows, and a more formal DD analysis in Appendix A.3 confirms, that we need to design an empirical model of the effects of the oil spill that addresses two identification issues. First, it must account for the potentially localized effects of the spill without ignoring potential regional effects or giving rise to power issues. Second, it must ensure causal identification based on appropriate counterfactuals by addressing differences in the housing market crash experiences of different communities that are not fully captured by available controls. In this section, we outline a triple-difference

[27] To ensure that the effects of the crash are not simply due to our given definition of treatment and control groups, we present trend analysis based on two additional definitions in Appendix A.3. Results are qualitatively similar. Additionally, to rule out that the conclusions drawn from the figure are due to the unconditional nature of the plotted averages, in the same section we perform a formal DD analysis that controls for additional covariates. The analysis provides additional evidence that the crash befuddles estimation of the effects of the spill.

Figure 5: Average HPI over Time by Distance to Observed Oil



estimator that succeeds in both dimensions.

We proceed by presenting a simple model that formally illustrates the challenges to identification we face and motivates our DDD specification. Next, we define each of our treatment and control groups. Third, we specify our DDD regression equation and report our main results. Then, we conduct an event study analysis to provide evidence that our estimates recover the causal estimates of effects of the spill and examine how those effects evolved over time. Next, we show that spill effects decline with distance from affected areas. Finally, we examine whether different levels of oil damage have different effects on the housing market.

3.1 Intuitive Model

We follow the approach of Muehlenbachs et al. (2015) by using a simple model to formalize the confounding factors our empirical strategy must confront in order to separately identify the effects of the oil spill. Let markets in the Gulf region fall into one of four areas indexed by $j = \{TC, TI, UC, UI\}$: (i) the treated coast (TC), (ii) the treated interior (TI), (iii) the untreated coast (UC), and (iv) the untreated interior (UI). Define the change over time in the housing market in a given area as ΔP_j. These temporal changes are a function of area-specific factors:

$$\begin{aligned}
\Delta P_{TC} &= \Delta Macro + \Delta Region_A + \Delta Coast + \Delta Oil \\
\Delta P_{TI} &= \Delta Macro + \Delta Region_A + \Delta Interior \\
\Delta P_{UC} &= \Delta Macro + \Delta Region_B + \Delta Coast \\
\Delta P_{UI} &= \Delta Macro + \Delta Region_B + \Delta Interior.
\end{aligned}$$

The $\Delta Macro$ term represents economy-wide changes such as the housing market crash. Similarly, the $\Delta Region$ term captures changes in the local economy. As the Gulf region is large and economically diverse, we allow these changes to potentially differ between the treated and untreated areas.[28] Next, the $\Delta Coast$ and $\Delta Interior$ terms account for heterogeneous changes in beach and inland housing markets due to fundamental differences between the two types of communities. For instance, coastal markets contain relatively more vacation homes, have a greater percentage of rental properties, are populated by citizens with a different distribution of incomes and credit constraints, and have labor markets more heavily dependent on tourism and Gulf recreation than interior communities. All of these factors are likely to contribute to the differential housing market crash experiences of coastal communities and their inland neighbors. Finally, the ΔOil term reflects the net effects of the oil spill damage and subsequent restoration and restitution efforts. Our goal is to develop an estimator that separately identifies this term.

To do so, we use a triple-difference estimator. The first difference is represented by the Δ operators. It reflects the temporal difference in markets before and after the spill. Next,

[28] Note that there are likely to be multiple local market effects in the treated and untreated areas (e.g., $\Delta Region_B = \Delta Region_C + \Delta Region_D$). This does not affect identification so long as those regional effects are the same in both the coastal and interior areas within the treated and untreated regions.

we difference the treated coast and interior:

$$\Delta P_{TC} - \Delta P_{TI} = \Delta Coast - \Delta Interior + \Delta Oil.$$

This DD estimator is akin to the one presented in the analysis of trends in Section 2.3. It illustrates the confounding effects of the crash due to the differences in changes in coastal and inland markets.[29] By taking an additional difference, we can address this issue since

$$\Delta P_{UC} - \Delta P_{UI} = \Delta Coast - \Delta Interior.$$

Thus, our DDD estimator differences away all confounding effects and separately identifies the effects of the spill:

$$(\Delta P_{TC} - \Delta P_{TI}) - (\Delta P_{UC} - \Delta P_{UI}) = \Delta Oil.$$

3.2 Treatment and Control Groups

To implement an empirical analog to our intuitive model, we define four different groups based on the theoretical areas defined in the previous section: (i) coastal ZIP Codes affected by the spill (TC), (ii) interior ZIP Codes affected by the spill (TI), (iii) coastal ZIP Codes unaffected by the spill (UC), and (iv) interior ZIP Codes unaffected by the spill (UI). We consider every ZIP Code in the Gulf States and Georgia and assign them into one of these four groups based on the combination of their proximity to the coast and their proximity to the nearest surveyed segment of the coast. For robustness, we vary the distance cutoffs that define these four groups.

We define a ZIP Code as coastal based on the distance from the ZIP Code to the nearest location on either the Gulf or Atlantic Coast. For our primary analysis, we consider three different coastal distance cut-offs: zero, five and ten miles. In subsequent analysis, we vary these distances to estimate a distance gradient and confirm that the effects of the spill lessen as one moves farther from oil damage. Similarly, we define a jurisdiction as treated based on the distance from the ZIP Code to the nearest location that was surveyed by a SCAT team. In the analysis that follows, we vary how many miles from a surveyed location is considered

[29] A DD estimator based on instead differencing the treated and untreated coastal regions results in a similar issue:

$$\Delta P_{TC} - \Delta P_{UC} = \Delta Region_A - \Delta Region_B + \Delta Oil.$$

as treated. The three variations we present are 100, 125, and 150 miles.[30]

We begin the construction of our DDD estimator by interacting these two group definitions to form the four groups mentioned previously. Figure 6 presents a map that describes the distribution of ZIP Codes among these four groups for the ten-mile coastal distance cutoff and the 125-mile interior treatment definition. For this treatment definition, (i) coastal ZIP Codes affected by the spill are those that are both within ten miles of a coast and within 125 miles of a coastal segment inspected by a SCAT team. This group is labeled "Treated Coast" and shaded in dark gray on the maps. Similarly (iii) coastal ZIP Codes unaffected by the spill are those within ten miles of the coast, but more than 125 miles of a coastal segment inspected by a SCAT team. This group is shaded dark red and referred to as "Untreated Coast" on the maps. The (ii) interior ZIP Codes affected by the spill are labeled "Treated Interior" and shaded in light gray, and the (iv) interior ZIP Codes unaffected by the spill are the "Untreated Interior" locations shaded in light red. Both groups are made up of ZIP Codes more than ten miles from a coast. The former group is comprised of those within 125 miles of a segment inspected by a SCAT team, and the latter are more than 125 miles away from a surveyed segment.[31]

3.3 DDD Regression Model Estimators

To obtain an estimate of the effect of interest we difference three times: (i) between treatment and control, (ii) between interior and coastal, and (iii) before and after the oil spill. In order to control for additional factors that could potentially affect housing markets and to compute standard errors that account for temporal correlation (Bertrand et al., 2004), we use a regression model specification. Our estimates are obtained by estimating the following model:

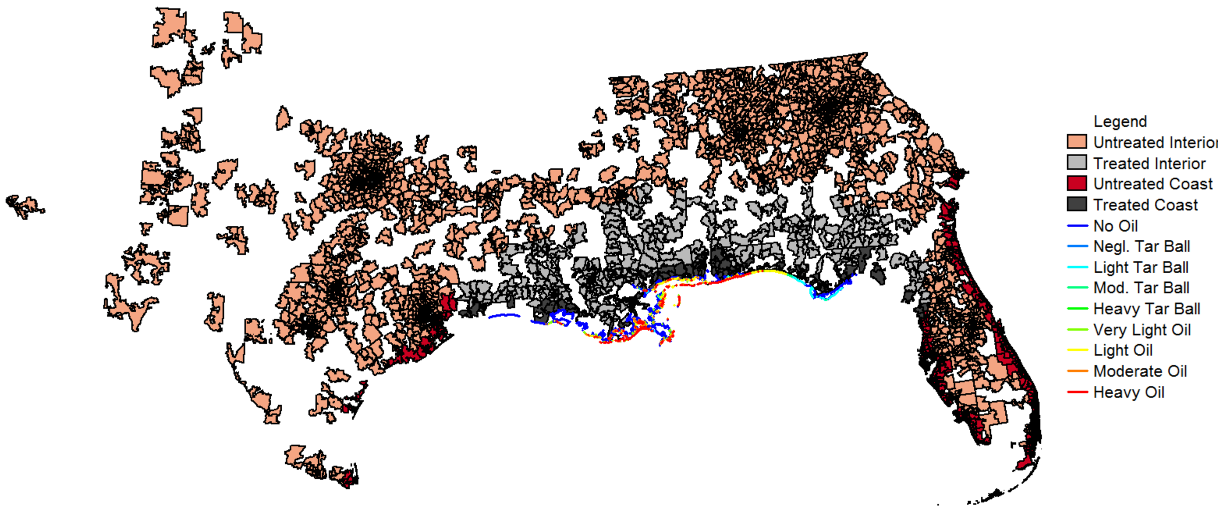
$$\ln(p_{it}) = \alpha_t + \gamma_i + \theta_1 D_t G_i + \theta_2 D_t C_i + \beta D_t C_i G_i + X_{it}\delta + \varepsilon_{it}, \tag{1}$$

where $\ln(p_{it})$ is the natural logarithm of the house price index in ZIP Code i in year t. D_t is an indicator variable equal to zero 0 for years 2005-2009 and equal to 1 for years 2010-

[30] We also consider 25, 50, 75, 175, and 200 mile definitions and results are very similar. We consider models based on the 100, 125, and 150 treatment definitions our preferred specifications out of an abundance of caution because event study analyses indicate that they produce the most comparable set of treatment and control groups. For instance, for the five-mile definition of a coastal ZIP Code and treatment definitions of 150 miles or less, the only year-specific estimate of the difference between the treated-coast and the control groups that ever significantly differs from zero in the pre-spill period is in 2005 (the same year as Hurricane Katrina). See Sections 3.4 and 3.6 for more detail.

[31] The descriptions of these four groups using the zero and five mile criteria for coastal ZIP Code are analogous. See Appendix A.4 for the accompanying maps.

Figure 6: Coastal and Interior Treatment and Control Groups (Ten-Mile Coastal; 125-Mile Interior)



2016. The latter period encompasses all of the most current HPI data available. We begin our analyses in 2005 as Hurricane Katrina made landfall in both Florida and Louisiana in August of that year. There is evidence that the hurricane resulted in persistent changes to housing markets (Deryugina et al., 2014; Bleemer and Van der Klaauw, 2017). We restrict our samples to the period after this structural change to ensure accurate comparisons with the post oil spill period. G_i is an indicator variable equal to 1 if ZIP Code i is considered treated by oil damage and 0 otherwise. C_i is an indicator equal to 1 if i is a coastal ZIP Code and 0 if it is inland. X_{it} is a vector of potential controls. In Appendix A.2, we present figures that show substantial time-varying, spatial clustering at both the state and sub-state levels. To control for this spatio-temporal variation, we include both state-by-year fixed effects and county-specific linear and quadratic time trends in our models. Finally, the α_t and γ_i are year effects and ZIP Code fixed effects, respectively. The DDD parameter is β which represents the effect of the oil spill on a ZIP Code in the treated, coastal group.

Table 4 presents the estimates of β for various definitions of coastal and treatment based on distance. Columns (1) - (3) present three cases of the interior treatment definition (100, 125, and 150 miles from surveyed locations) when the definition of a coastal ZIP Code is one that contains the coastline (ZIP Codes zero miles from the coast). The coefficient estimates indicate that the estimate of the effect of the oil spill on the price of homes along the coast is a decrease of between 8.1 and 8.3 percent. Columns (4) - (6) and (7) - (9) present the same three cases of the treatment definition when the coastal definitions are ZIP Codes within five and ten miles from the coast, respectively. The results in each of these three sets of columns are are remarkably similar. This suggests that the estimates are very robust to the definition of treatment. Looking across coastal definitions, an intuitive pattern emerges. The magnitude of the estimated effect declines as the coastal definition increases. Homes in ZIP Codes further from the coast are less likely to be physically affected by oil, and they derive less of their value from proximity to the Gulf. Thus, we would expect the effect to attenuate. We examine the spatial decay in our estimates in more detail in Section 3.6 after providing evidence that our estimates can be interpreted as causal.

3.4 Identification

The nature of the event under study motivates the use of a DDD strategy. Given that the spill affected all communities at the same point in time, identification of the causal effects of the oil spill on home prices requires that the event causing the treatment occurred at random. The context of our research design satisfies this criteria for two reasons. First, as the result of an unexpected and unfortunate accident, the BP oil spill represents an exogenous shock to the housing market in the affected areas. There is no reason to believe that housing market factors played a role in causing the spill. Second, ocean currents dictated where the spilled oil went, and as a result, damage was not uniformly distributed along the Gulf Coast. Only some coastal areas actually experienced any damage.

While this condition is necessary for causal identification, it is not sufficient. It must also be the case that, conditional on observable factors, our model differences away all remaining unobservable factors and returns only the effects of the spill. Intuitively, this can be thought of as the condition that the treatment and control jurisdictions would have experienced similar outcomes in the absence of the spill. This is commonly known as the parallel trends assumption in the DD context. Visual analysis of trends in the HPI is complicated in this setting with multiple different groups and is not conditional on available control measures. Instead, we present an event study in which we estimate the following regression:

$$\begin{aligned} \ln(p_{it}) = {} & \alpha_t + \gamma_i + \theta_1 D_t G_i + \theta_2 D_t C_i \\ & + \sum_{t \neq 2009} \beta_t \mathbf{1}\{t\} C_i G_i + X_{it}\delta + \varepsilon_{it}, \end{aligned} \tag{2}$$

where $\ln(p_{it})$, α_t, γ_i, D_t, G_i, C_i, and X_{it} are defined as in Equation 1; and $\mathbf{1}\{t\}$ is an indicator

Table 4: DDD Estimates

	Zero-Mile Coastal Definition Interior Treatment Definition			Five-Mile Coastal Definition Interior Treatment Definition			Ten-Mile Coastal Definition Interior Treatment Definition		
	100 mi	125 mi	150 mi	100 mi	125 mi	150 mi	100 mi	125 mi	150 mi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$D_t \times G_i \times C_i$	-0.0808***	-0.0826***	-0.0824***	-0.0511***	-0.0521***	-0.0519***	-0.0429***	-0.0437***	-0.0417***
	(0.0155)	(0.0153)	(0.0142)	(0.0113)	(0.0110)	(0.0102)	(0.0107)	(0.0102)	(0.00945)
Controls:									
ZIP Code effects	y	y	y	y	y	y	y	y	y
Year effects	y	y	y	y	y	y	y	y	y
County-spec. linear trend	y	y	y	y	y	y	y	y	y
County-spec. quadratic trend	y	y	y	y	y	y	y	y	y
State $\times$ year effects	y	y	y	y	y	y	y	y	y
No. of ZIP Codes in:									
Control interior	2579	2501	2380	2579	2501	2380	2579	2501	2380
Treatment interior	387	463	570	434	512	633	434	512	633
Control coast	155	153	144	373	370	359	520	515	499
Treatment coast	47	49	58	89	92	103	124	129	145
Sample size	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602
R^2	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.

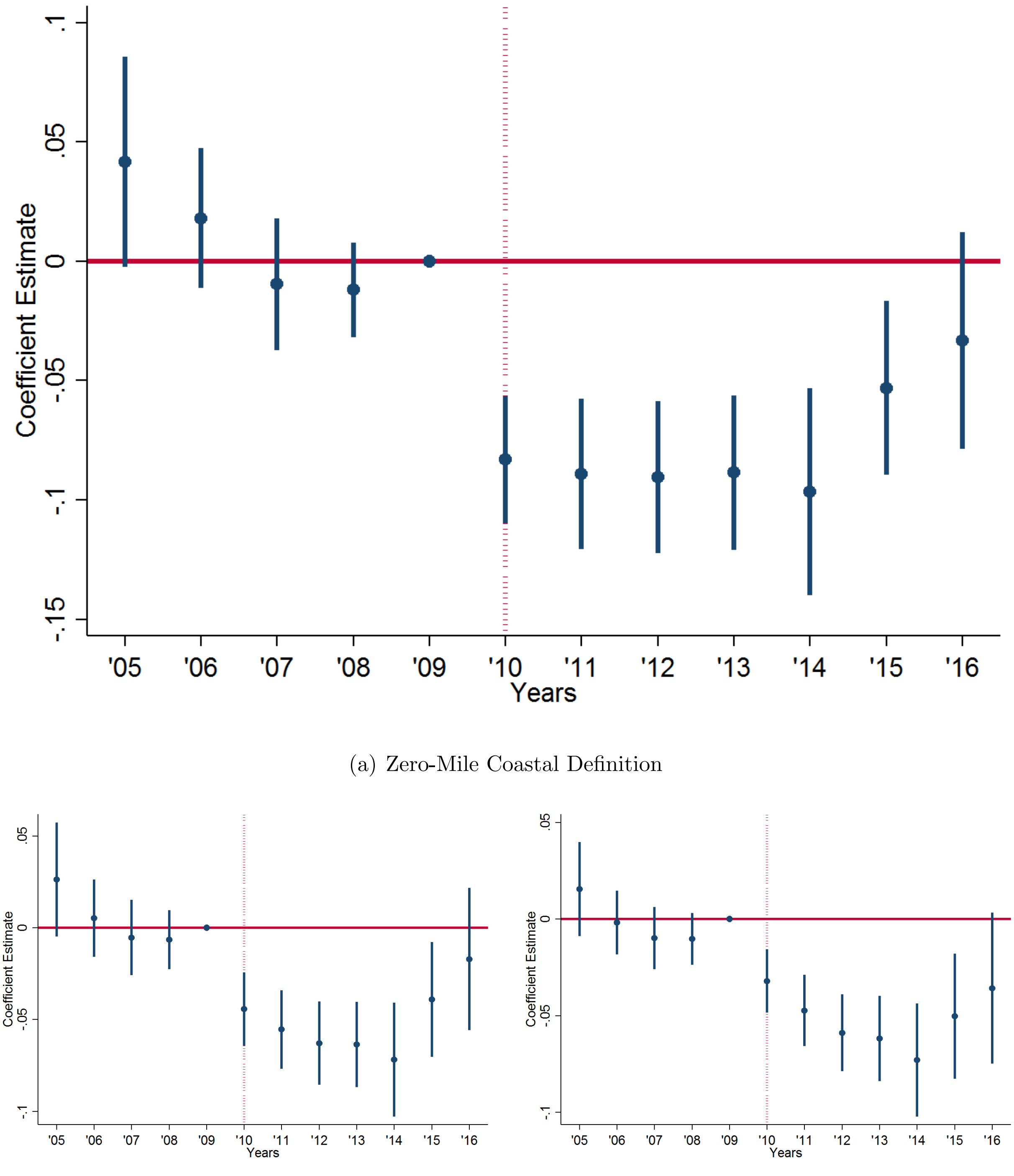
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

function for each given year from 2005 to 2016. We omit the year before the spill, 2009, to avoid perfect collinearity.

We are interested in the estimates of β_t for each of these years. The $\hat{\beta}_t$ for each year for both the zero-, five-, and ten-mile definitions of coastal ZIP Codes and the 125-mile definition of treatment are presented in Figure 7 together with their corresponding 95% confidence intervals.[32] The pre-spill estimates are all statistically insignificant, indicating that housing markets in eventually treated coastal locations were no different than their control group neighbors prior to the spill. These pre-spill estimates suggest that our DDD model recovers the causal effect of the spill. As the pictures indicate, after the oil spill occurred in 2010, home prices in the coastal treatment group experienced a statistically significant decrease in prices that persisted for five years before eventually returning to baseline in 2016.

[32] Patterns are similar for our other treatment distance cutoff definitions. A full table of coefficient estimates for each of our definitions can be found in Appendix A.5.

Figure 7: DDD Event Study Estimates (125-Mile Interior)



(a) Zero-Mile Coastal Definition

(b) Five-Mile Coastal Definition

(c) Ten-Mile Coastal Definition

3.5 Placebo and Permutation Tests

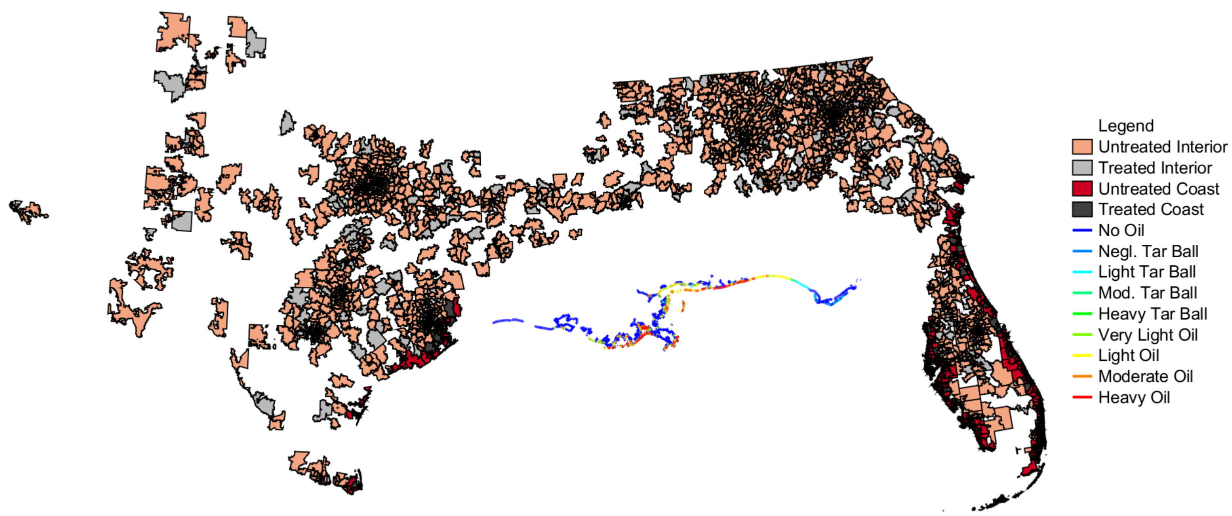
To provide additional support for the interpretation of our estimates as the causal net effect of the spill, we perform placebo and permutation tests. These related analyses have two benefits. First, by comparing our estimates to those based on placebo groups, we are able to show that our results are unlikely to occur because of random, unmodeled factors. In other words, the signs and magnitudes of our main estimates are almost assuredly the result of the spill. Second, the nonparametric permutation test allows us to calculate empirical p-values for the null hypothesis that the coefficient of interest $\beta = 0$. Calculation of these p-values requires no assumptions about the error structure, so they are not biased by spatial or temporal autocorrelation (Chetty et al., 2009). Thus, the permutation test provides an additional way to address the potential bias that leads to the the overrejection concerns raised by Bertrand et al. (2004). The test confirms that our cluster-robust specification adequately addresses this issue.

In order to perform these tests, we remove the actual treated coast and interior from our sample. Resampling from the remaining ZIP Codes gives the empirical distribution of $\hat{\beta}$ under the null of $\beta = 0$ under the assumption that the remaining ZIP Codes are unaffected by the spill. We then randomize which ZIP Codes are considered to be members of each of the four treated/untreated and coastal/interior groups. As an illustration, Figure 8 displays the spatial distribution of treatment and control groups for one placebo draw based on the ten-mile coastal and the 125-mile treatment distance definitions.[33] We then re-estimate Equation 1 with indicators based on the placebo group definitions. Our permutation test algorithm repeats these placebo tests $10,000$ times, saving the resulting placebo estimates of the coefficient of interest. Letting r denote the placebo draw, we denote the rth placebo estimate of β as $\tilde{\beta}_r$.

Figure 9 displays the results of our analyses. Subfigure 9(a) plots a histogram of the $\tilde{\beta}_r$. Consistent our expectations, the placebo estimates are centered on a mean of zero with a standard deviation, 0.0104, that is roughly equivalent to the standard error of the corresponding estimate of β from Table 4. The mean shows that our empirical specification finds no difference between treatment and control groups in the absence of oil damage. In contrast, the corresponding estimate of β from Table 4 is -0.0437 (denoted by the vertical, dashed line). This estimate is over four standard deviations from the mean. Taken together, the figure illustrates that obtaining our coefficient estimate would be an extremely low prob-

[33] Note that in contrast to Figure 6, the large white area to the north of the observed oil damage represents treated ZIP Codes that are removed from the sample.

Figure 8: Example of Placebo Treatment and Control Groups by Coastal and Interior (Ten-Mile Coastal; 125-Mile Interior)

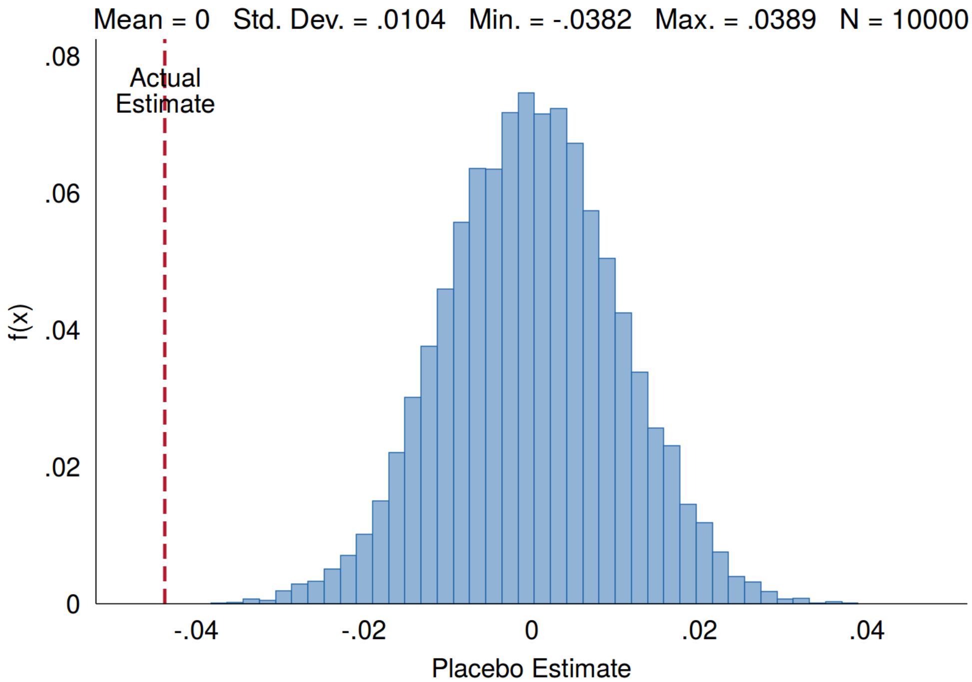


ability event if the oil damage caused by the spill had no effect on housing markets. This is a rejection of the null hypothesis that $\beta = 0$.

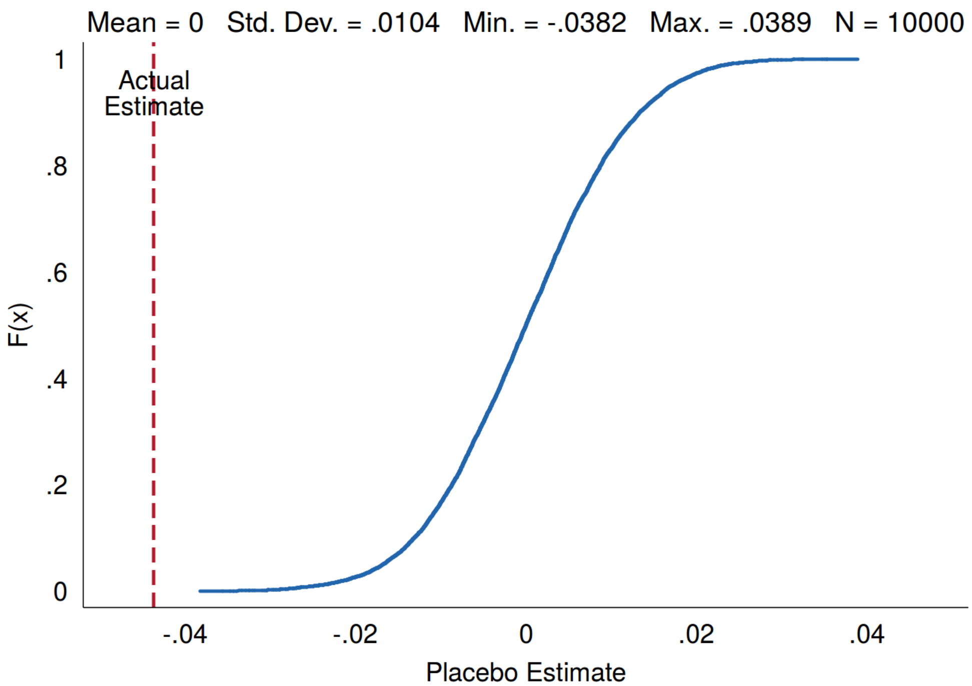
Subfigure 9(b) presents the results of the nonparametric permutation test. The figure plots the empirical cumulative distribution function, $F\left(\tilde{\beta}_r\right)$, that corresponds to the density of the $\tilde{\beta}_r$s represented by the histogram in Subfigure 9(a). In general, the value of the $F\left(\tilde{\beta}_r\right)$ at the corresponding estimate of β from Table 4 (again, represented by the vertical, dashed line) gives the empirical p-value for the null hypothesis that the coefficient of interest is zero. In this case, that $F\left(\tilde{\beta}_r\right)$ and the vertical line do not intersect shows that the empirical p-value associated with our estimate is essentially zero.[34] Again, this is a rejection of the null hypothesis that $\beta = 0$ and a confirmation of the validity of our DDD regression results.

[34] The lack of an intersection indicates a result that is so good it is "off-the-charts."

Figure 9: Empirical Density and Distribution of Placebo Estimates



(a) Empirical Density



(b) Empirical Distribution

3.6 Spill Effects by Distance

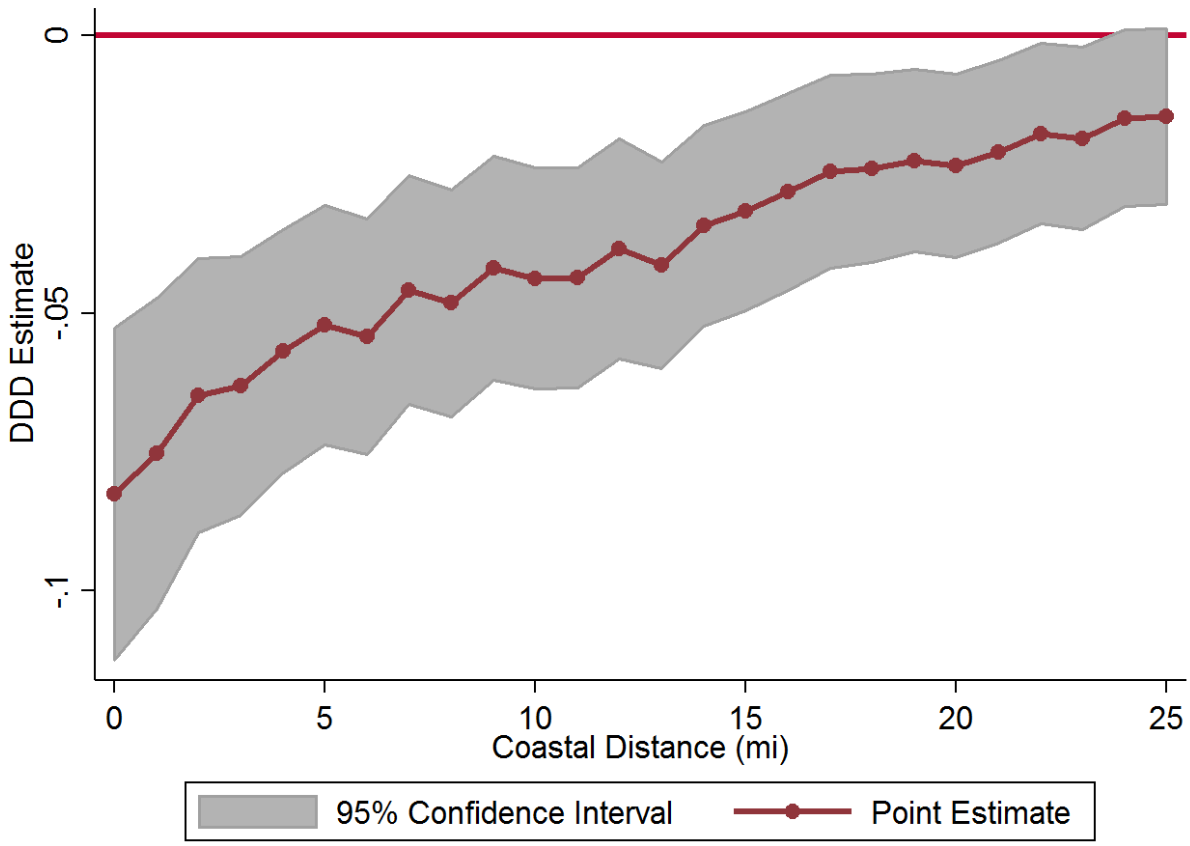
Decreases in the magnitudes of the estimates in Sections 3.3 and 3.4 as we consider broader coastal communities as treated are consistent with our exploratory finding that the effects of the spill are potentially localized to the coast. They further suggest an intuitive finding that the spill may have had more pronounced effects near the coast, but that those effects dissipated with distance. Table 5 provides robust evidence that this is the case. The table is based on the 125-mile treatment definition and varies by the coastal definition distance from zero miles (ZIP Codes that contain surveyed segments) in Column (1) up to 25 miles in Column (8). Panel A of the table reports estimates of our main model (Equation 1), and Figure 10 represents this information visually. Both show that the magnitudes of the estimated effects decline as the definition of treated coastal housing markets includes more inland communities. These effects are significant at the 5% level until around 25 miles. Panel B of the table indicates that there is strong evidence that these models control for all confounding effects out to a coastal definition of at least ten miles. Despite possible concerns beyond ten miles, the panel also indicates that the year-by-year estimates from the event study specification (Equation 2) show a remarkably robust pattern of results at all distances.

Table 5: DDD Estimates by Coastal Definition Distance (125-Mile Interior)

	Coastal Definition							
	0 mi	1 mi	3 mi	5 mi	10 mi	15 mi	20 mi	25 mi
	(1)	(2)	(3)	(4)	(5)	(6)	7)	(8)
Panel A: Main Model Estimates								
$D_t \times G_i \times C_i$	-0.0826***	-0.0753***	-0.0631***	-0.0521***	-0.0437***	-0.0316***	-0.0234***	-0.0145*
	(0.0153)	(0.0143)	(0.0119)	(0.0110)	(0.0102)	(0.00918)	(0.00841)	(0.00810)
Panel B: Event Study Estimates								
$\mathbf{1}\{2005\} \times C_i \times G_i$	0.0416*	0.0451**	0.0344**	0.0263*	0.0154	0.00730	-0.000132	-0.0105
	(0.0225)	(0.0212)	(0.0175)	(0.0159)	(0.0124)	(0.0112)	(0.0106)	(0.00916)
$\mathbf{1}\{2006\} \times C_i \times G_i$	0.180	0.0152	0.0122	0.00528	-0.00192	-0.00472	-0.0105	-0.0219***
	(0.0150)	(0.0143)	(0.0118)	(0.0107)	(0.00840)	(0.00771)	(0.00768)	(0.00655)
$\mathbf{1}\{2007\} \times C_i \times G_i$	-0.0096	-0.00595	-0.00497	-0.00540	-0.00996	-0.0129*	-0.0171**	-0.0259***
	(0.0141)	(0.0133)	(0.0111)	(0.0105)	(0.00821)	(0.00738)	(0.00700)	(0.00633)
$\mathbf{1}\{2008\} \times C_i \times G_i$	-0.0120	-0.0104	-0.00940	-0.00653	-0.0103	-0.0125**	-0.0151***	-0.0198***
	(0.0101)	(0.00947)	(0.00792)	(0.00820)	(0.00681)	(0.00604)	(0.00543)	(0.00504)
$\mathbf{1}\{2009\} \times C_i \times G_i$	-	-	-	-	-	-	-	-
$\mathbf{1}\{2010\} \times C_i \times G_i$	-0.0831***	-0.0751***	-0.0552***	-0.0443***	-0.0321***	-0.0263***	-0.0231***	-0.0171**
	(0.0136)	(0.0127)	(0.0104)	(0.0102)	(0.00838)	(0.00815)	(0.00742)	(0.00727)
$\mathbf{1}\{2011\} \times C_i \times G_i$	-0.0891***	-0.0807***	-0.0666***	-0.0554***	-0.0473***	-0.0382***	-0.0324***	-0.0241***
	(0.0160)	(0.0148)	(0.0119)	(0.0109)	(0.00942)	(0.00883)	(0.00796)	(0.00770)
$\mathbf{1}\{2012\} \times C_i \times G_i$	-0.0906***	-0.0814***	-0.0725***	-0.0629***	-0.0589***	-0.0485***	-0.0407***	-0.0362***
	(0.0163)	(0.0154)	(0.0129)	(0.0115)	(0.0101)	(0.00925)	(0.00824)	(0.00817)
$\mathbf{1}\{2013\} \times C_i \times G_i$	-0.0886***	-0.0795***	-0.0732***	-0.0637***	-0.0618***	-0.0505***	-0.0429***	-0.0407***
	(0.0164)	(0.0157)	(0.0130)	(0.0119)	(0.0113)	(0.00969)	(0.00859)	(0.00862)
$\mathbf{1}\{2014\} \times C_i \times G_i$	-0.0966***	-0.0908***	-0.0811***	-0.0719***	-0.0730***	-0.0577***	-0.0468***	-0.0453***
	(0.0221)	(0.0206)	(0.0168)	(0.0158)	(0.0149)	(0.0119)	(0.0101)	(0.0101)
$\mathbf{1}\{2015\} \times C_i \times G_i$	-0.0531***	-0.0482***	-0.0462***	-0.0391**	-0.0503***	-0.0379***	-0.0304***	-0.0327***
	(0.0186)	(0.0176)	(0.0152)	(0.0160)	(0.0165)	(0.0124)	(0.0104)	(0.0107)
$\mathbf{1}\{2016\} \times C_i \times G_i$	-0.0332	-0.0210	-0.0239	-0.0171	-0.0358*	-0.0209	-0.00840	-0.0139
	(0.0231)	(0.0223)	(0.0188)	(0.0198)	(0.0200)	(0.0146)	(0.0117)	(0.0126)
No. of ZIP Codes in:								
Control coast	49	54	76	92	129	164	201	236
Treatment coast	153	196	291	370	515	593	647	710
Sample size	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602
R^2	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state × year effects; and county-specific linear and quadratic trends.

Figure 10: Housing Market Effects of Oil Damage by Coastal Definition Distance (125-Mile Interior)



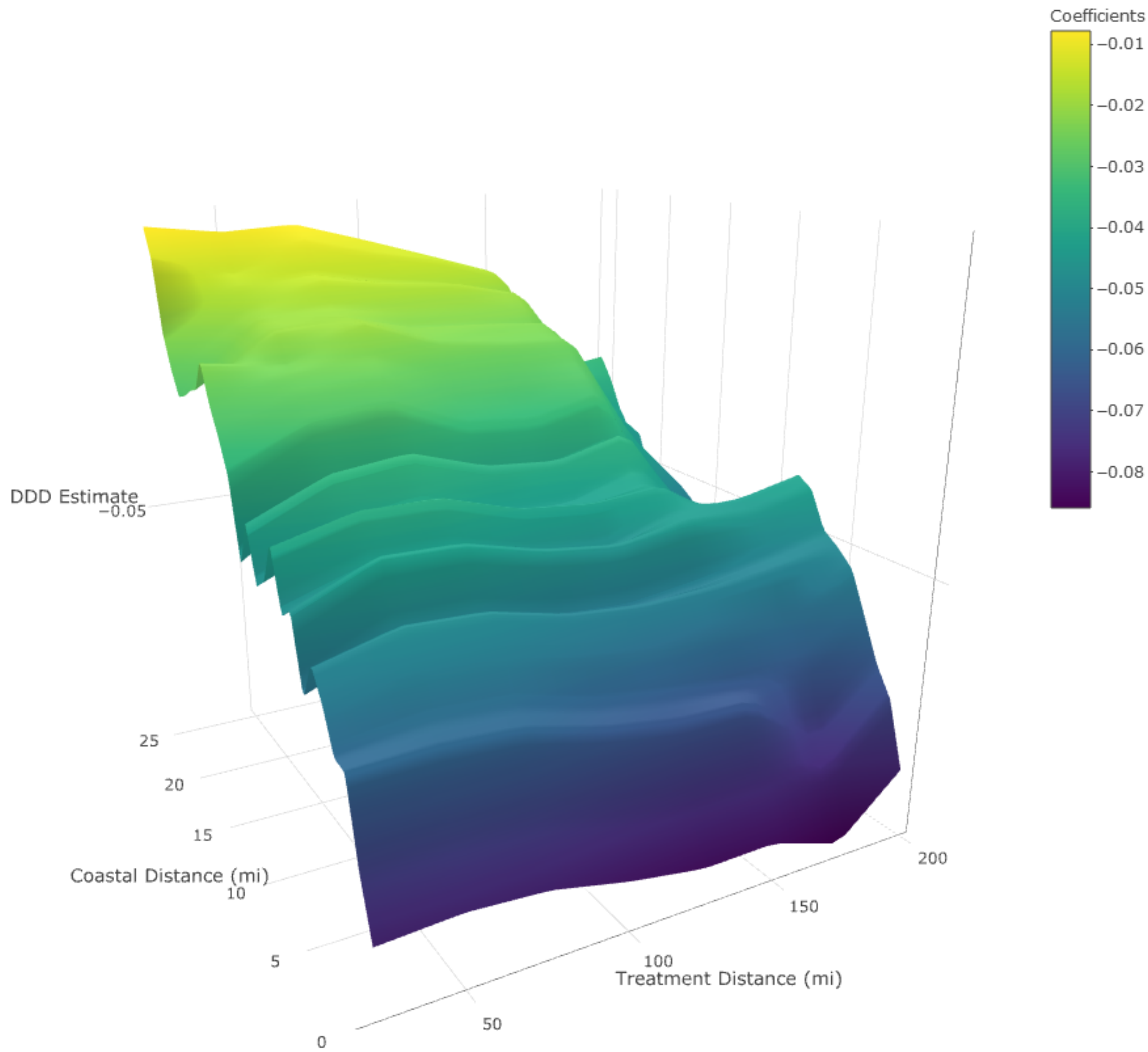
We provide analogous tables for the 100- and 150-mile definitions in Appendix A.6. Both report estimates of the aggregate effect of the spill that are remarkably similar to those found in Panel A of Table 5. Also, both indicate that the parallel pre-trends assumption is less likely to be satisfied when ZIP Codes more than ten miles from the shoreline are defined as coastal. Additionally, the overall pre-trends in the 150-mile definition are weaker than those based on the 100- and 125-mile definitions. Thus, we conclude that definitions of the coast that extend to about ten miles and definitions of treatment that include ZIP Codes within about 125 miles of the surveyed coast are likely to control for all non-spill related factors that affected treated coastal communities in the post-spill period.

With this in mind, we plot the coefficient estimates from our DDD model (Equation 1) using various combinations of both treatment and coastal definition distances in Figure 11.[35]

[35]We provide a table of all plotted estimates and associated standard errors in Appendix A.7.

The x- and y-axes in the figure vary our distance definitions, and the z-dimension represents the magnitude of the coefficient estimate. The figure illustrates how robust our estimates are. Consistent with previous results, the magnitude of the effect of the spill decreases as distance from the coast increases, but is relatively constant as distance to the closest surveyed coastal segment varies. The only exception to this pattern occurs for both coastal definitions beyond ten miles and treatment definitions beyond 150 miles where the effect of the spill is not well identified.

Figure 11: Housing Market Effects of Oil Damage by Interior Treatment and Coastal Definition Distances



3.7 Spill Effects by Intensity of Damage

As Figure 2 illustrates, oil damage to the Gulf Coast was not uniformly distributed. This suggests an alternative DDD strategy that defines areas affected by spill damage based not just on their proximity to the surveyed coast, but also based on the intensity of the nearest oil damage. Table 2 indicates that SCAT survey teams did not find oil damage falling into all possible intensity categories; some of the nine different oil damage categories in the table contain only trivial mass. To address this issue, we aggregate the nine SCAT categories into two damage super-categories for our analysis: tar balls and oil.[36] We then define two mutually exclusive treatment groups based on the distance to the nearest observed aggregate oil category and modify our DDD model specification from Equation (1) accordingly.[37] Explicitly,

$$\begin{aligned} \ln(p_{it}) = \alpha_t + \gamma_i + \theta_1 D_t G_i^{TB} + \theta_2 D_t G_i^{Oil} + \theta_3 D_t C_i \\ + \beta_1 D_t C_i G_i^{TB} + \beta_2 D_t C_i G_i^{Oil} + X_{it}\delta + \varepsilon_{it}, \end{aligned} \tag{3}$$

where G_i^{TB} is an indicator equal to 1 if the ZIP Code is in the tar ball treatment and 0 otherwise, and G_i^{Oil} is equal to 1 if in the oil treatment. All other variables and parameters are defined as in Equation 1. The coefficients of interest are β_1 and β_2. Partitioning the treatment group into subgroups and estimating separate, damage-specific effects in this way allows us to investigate those damage-specific impacts both individually (relative to an unaffected control group) and relative to one another.[38]

Table 6 presents estimates of the parameters of interest in the first two rows for various definitions of coastal and treatment.[39] For each of our three treatment definitions with a

[36]The tar balls category is comprised of segments recorded as falling into the "negligible" through "heavy tar balls" categories. The oil category contains segments recorded as having "light oil" through "heavy oil." See Section 2.2 for more detail.

[37]See Appendix A.8 for a map that depicts which ZIP Codes fall into each treatment group.

[38]We use a similar empirical specification to test for heterogeneity in the effects of the spill by regions depending on the structure of their local economies. With the exception of the tourism in New Orleans, much of the Gulf economy in Louisiana is tied to oil prices. The surrounding areas of East Texas and Mississippi are much the same. This contrasts with the largely tourism based Gulf economies of South Texas, Alabama, and Florida. Due to these stylized facts, we partition the dataset into two different groups: (i) Florida, Alabama, and South Texas; (ii) Louisiana, Mississippi, and East Texas. Analogous to the DDD effects by intensity we describe in this section, we estimate separate effects for each region. Unfortunately, dividing the sample in this way makes it difficult to define appropriate treatment and control groups. Event study estimates indicate that we are unable to satisfy the parallel pre-trends assumption for either of the regions defined. Results of this analysis are available from the authors by request.

[39]See Appendix A.9 for event study estimates that correspond to this analysis. We note that event study specifications of these models yield estimates that indicate that the parallel pre-trends assumption is more

coastal cutoff of zero miles in Columns (1) - (3), the point estimates indicate that homes in proximity to oil damage suffered a greater decrease in value than homes in proximity to segments damaged by tar balls. However, the third row indicates that these differences are not statistically significant. Estimates for the other distance based group definitions in the remaining columns show an opposite pattern (tar balls caused greater damage than oil). Again, the differences are not statistically different. While we hesitate to draw conclusions from differences in estimates that are not statistically significant, if we take the differences at face value, two-thirds of our specifications yield counterintuitive results. We note that the overall pattern of results is not as surprising as it might seem. As the distance from the nearest oil damaged location increases, it becomes increasingly likely that a treated ZIP Code is only marginally more proximate to one category of damage than the other. This makes the distinction between the tar ball and oil treatment groups less meaningful, and would explain why the difference in estimates has the expected sign only in models based on treated groups close to the coast in Columns (1) - (3). Overall, we find suggestive evidence that more intense oil damage leads to greater decreases in housing values, but we are unable to conclude that this is the case.

3.8 Economic Significance

Our estimates indicate the percent change in single-family housing values caused by the oil spill. We do not observe house prices in our data, only the HPI, so we are unable to directly estimate an analogous effect in dollars. In order to better illustrate the extent of the damage caused by the spill, we perform back-of-the-envelope calculations to determine the total housing value our estimates indicate was lost. To do so, we obtain counts of housing units (United States Census Bureau / American FactFinder, 2015a) and estimates of median housing values (United States Census Bureau / American FactFinder, 2015b) by ZIP Code from the U.S. Census Bureau, 2011-2015 American Community Survey (ACS) 5-Year Estimates for the universe of all housing units. We use counts of all single-family attached and detached units by ZIP Code multiplied by the median housing value in the jurisdiction to obtain an estimate of the total value of the single-family housing stock in each ZIP Code.[40] We use the HPI to adjust these values so they reflect the total value of

tenuous for these models than in previous analyses, particularly for the tar ball category.

[40]Ideally, we would use a measure of the mean, not the median, in order to determine the total housing value, but an estimate of that moment is not available. To the extent that the distribution of housing values is in a ZIP Code right skewed, our figures are an underestimate of the total value. We believe this is likely to be the case, particularly in coastal communities where high value homes are built on the beach and the

Table 6: Damage Intensity DDD Estimates by Interior Treatment and Coastal Definition

	Zero-Mile Coastal Definition Interior Treatment Definition			Five-Mile Coastal Definition Interior Treatment Definition			Ten-Mile Coastal Definition Interior Treatment Definition		
	100 mi	125 mi	150 mi	100 mi	125 mi	150 mi	100 mi	125 mi	150 mi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$D_t \times C_i \times G_i^{TB}$	-0.0511**	-0.0588***	-0.0641***	-0.0556***	-0.0588***	-0.0583***	-0.0640***	-0.0642***	-0.0552***
	(0.0212)	(0.0204)	(0.0170)	(0.0164)	(0.0154)	(0.0135)	(0.0170)	(0.0153)	(0.0130)
$D_t \times C_i \times G_i^{Oil}$	-0.0910***	-0.0919***	-0.0924***	-0.0492***	-0.0492***	-0.0484***	-0.0347***	-0.0349***	-0.0336***
	(0.0175)	(0.0175)	(0.0167)	(0.0126)	(0.0124)	(0.0117)	(0.0114)	(0.0111)	(0.0107)
$\hat{\beta}_1 - \hat{\beta}_2$	0.0399	0.0331	0.0283	-0.0064	-0.0096	-0.0099	-0.0293	-0.0293	-0.0216
	(0.0275)	(0.0268)	(0.0238)	(0.0206)	(0.0197)	(0.0178)	(0.0204)	(0.0189)	(0.0168)
Controls:									
ZIP Code effects	y	y	y	y	y	y	y	y	y
Year effects	y	y	y	y	y	y	y	y	y
County-spec. linear trend	y	y	y	y	y	y	y	y	y
County-spec. quadratic trend	y	y	y	y	y	y	y	y	y
State × year effects	y	y	y	y	y	y	y	y	y
No. of ZIP Codes in:									
Control interior	2424	2348	2236	2206	2131	2021	2059	1986	1881
Tar Ball interior	100	134	183	85	119	167	69	102	146
Oil interior	287	329	392	260	301	363	241	281	342
Control coast	155	153	144	373	370	359	520	515	499
Tar Ball Coast	15	17	23	30	32	39	46	49	60
Oil Coast	32	32	35	59	60	64	78	80	85
Sample size	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602
R^2	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

the housing stock in 2009, the year before the spill. We then use these 2009 housing value estimates for the ZIP Codes in our estimation sample identified as being both treated, coastal in concert with the DDD estimates reported in Table 4 to estimate the net damage caused by the BP oil spill in dollars.

We use the 125-mile interior treatment definition for all of our economic significance calculations. When we do so, the zero-mile coastal point estimate of an 8.3 percent decrease in housing values corresponds to $3.8 billion of damage being capitalized by the housing markets, net of clean-up and restitution payments. The 95% confidence interval ranges from $2.4 billion to $5.2 billion. For the ten-mile coastal point estimate of a 4.4 percent decrease in net, capitalized losses that affected more locations, this represents a $5.0 billion loss in value (with a 95% confidence interval that ranges from $2.7 billion to $7.3 billion). We note that these estimates should be taken as a lower bound on the total damage caused by the spill for several reasons. First, they represent the net damage inclusive of BP's restitution and rehabilitation efforts. Second, they are only based on a fraction of all properties (single-family homes). Regardless, we note that our revealed-preference estimates are of the same order of magnitude as the Bishop et al. (2017) stated-preference methods estimate of total willingness to pay to avoid a future spill of $17.2 billion. Given that their methodology incorporates damage to all properties, we take the similarity of our estimates as further confirmation of our results.

4 Conclusion

The goal of this work is to determine the net effect of the BP oil spill on the housing market. To that end, we: (i) merge data on prices of single-family houses with data from a novel data set constructed from a survey on the location and severity of oil observed along the Gulf Coast, and (ii) perform a hedonic-style analysis in a triple-difference framework. We add to the literature by producing the first plausibly causal estimates of the effect of the BP oil spill on Gulf Coastal housing markets. Additionally, we analyze a different type of housing unit than in previous studies and perform the first housing market analysis that covers the entire affected geographical region by using data from the five Gulf adjacent states and Georgia. We depart from previous studies by making use of information on the actual locations of where oil damaged the coast and by using a geographically finer observational unit that allows us to control for state and local housing market effects.

size and value of homes decline quickly as the distance from the natural amenity increases.

Our estimates suggest that the BP oil spill caused a dramatic and robust decline in housing values of between four and eight percent that persisted until 2015. Our estimates imply a lower bound on the damage caused by the spill of between \$3.8 billion and \$5.0 billion. This effect was most pronounced in housing markets close to the coastal regions of the Gulf of Mexico. Our finding that the spill had large and persistent effects is noteworthy for several reasons. First, while video of oil flowing unchecked into the Gulf for several months and news reports of catastrophic impacts on the region were common, the response and clean-up efforts began mobilizing almost immediately. Based in part on NOAA's damage assessment that led to the collection of the oil survey data we make use of in this study, federal and state agencies prepared and are executing a comprehensive restoration plan as part of their mandates under the Oil Pollution Act of 1990 (OPA) and the National Environmental Policy Act (NEPA).[41] While this plan was not finalized until roughly six years after the spill began, restoration efforts were ongoing and expectations of future benefits would be capitalized by housing markets. As our analysis measures the net effect of the spill, to the extent that the restoration plan is adequate, we would not expect to find long-run effects on the housing market. Second, Aldy (2014) finds that the BP spill had an insignificant effect on Gulf labor markets as a whole, which is inconsistent with our findings unless the housing and labor markets capitalized the effects of the spill differently.[42] Third, our analysis is conducted at the finest geographic level for which we can obtain housing market data across the majority of the region, but ZIP Codes still cover large areas. To the extent that effects are greatest on properties that actually received oil damage or those in close proximity to the Gulf, our use of ZIP Codes will result in attenuated estimates of the effect of the spill. This suggests that our estimates are likely a lower bound on the true effect. Fourth, the spill occurred in late April of 2010. Since our data is at the annual level, transactions completed during more than one-third of our first treatment year were actually unaffected by the spill. As we would expect to find the most significant market effects shortly after the spill, again, this will attenuate our results and suggests our estimates are conservative with respect to the true effects.

[41] The "*Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement" outlines the full plan for recovery as part of a settlement BP reached with the government. The plan can be found at http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan/.

[42] Aldy (2014) also found that this net effect was due to offsetting sub-regional effects: economic activity was reduced along Florida's Non-Panhandle Gulf Coast, relatively flat in the Florida Panhandle, and actually improved in coastal communities in Alabama and Louisiana where employment is heavily concentrated in the oil industry. Unfortunately, we are unable to develop sub-samples that satisfy the parallel trends assumption that would allow us to examine heterogeneity in housing market effects.

We would be remiss if we did not offer a few caveats and suggestions of avenues for future research. First, we remind the reader that due to a limited number of transactions in areas with lower population densities, our results are conditional on the FHFA observing a sufficient number of transactions in each given ZIP Code and year to calculate the HPI. To the extent that the spill affected these low-density areas and more active markets differently, our results cannot be interpreted as the overall effect of the spill. Second, our data is limited to prices of only one type of housing: single-family homes. The Gulf Coast is also home to a large number of condominiums and commercial properties whose inclusion in future analyses may offer new insights. Finally, we note that researchers are just now beginning to understand the effects of the BP oil spill on many aspects of the economy, and investigation into the spill's effect on property values is far from complete. To the extent that data on additional types of properties at greater spatial and temporal frequencies becomes available, additional aspects of the spill can be investigated. Given present limitations, we leave additional questions to future research.

References

Aldy, Joseph E, "Real-Time Economic Analysis and Policy Development during the BP Deepwater Horizon Oil Spill," *Vanderbilt Law Review*, 2011, *64*, 1793.

Aldy, Joseph E., "The Labor Market Impacts of the 2010 Deepwater Horizon Oil Spill and Offshore Oil Drilling Moratorium," Working Paper 20409, National Bureau of Economic Research August 2014.

Barrage, Lint, Eric Chyn, and Justine Hastings, "Advertising as Insurance or Commitment? Evidence from the BP Oil Spill," Working Paper 19838, National Bureau of Economic Research January 2014.

Barrett, Devlin, "U.S., BP Finalize $20.8 Billion Deepwater Oil Spill Settlement," *The Wall Street Journal*, October 5 2015.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan, "How Much Should We Trust Differences-In-Differences Estimates?," *The Quarterly Journal of Economics*, 2004, *119* (1), 249.

Bishop, Richard C., Kevin J. Boyle, Richard T. Carson, David Chapman, W. Michael Hanemann, Barbara Kanninen, Raymond J. Kopp, Jon A. Krosnick, John List, Norman Meade, Robert Paterson, Stanley Presser, V. Kerry Smith, Roger Tourangeau, Michael Welsh, Jeffrey M. Wooldridge, Matthew DeBell, Colleen Donovan, Matthew Konopka, and Nora Scherer, "Putting a value on injuries to natural assets: The BP oil spill," *Science*, 2017, *356* (6335), 253–254.

Bleemer, Zachary and Wilbert Van der Klaauw, "Disaster (Over-)Insurance: The Long-Term Financial and Socioeconomic Consequences of Hurricane Katrina," FRB of NY Staff Report 807, Federal Reserve Banks - Federal Reserve Bank of New York February 2017.

Bogin, Alexander N., William M. Doerner, and William D. Larson, "Local House Price Dynamics: New Indices and Stylized Facts," FHFA Staff Working Paper 16-01, Federal Housing Finance Agency, Washington, DC June 2016.

Chetty, Raj, Adam Looney, and Kory Kroft, "Salience and Taxation: Theory and Evidence," *The American Economic Review*, 2009, *99* (4), 1145–1177.

Chiodo, Abbigail J., Rubén Hernández-Murillo, and Michael T. Owyang, "Nonlinear Effects of School Quality on House Price," *Federal Reserve Bank of St. Louis Review*, 2010, *92* (3), 185–204.

Deaton, B. James and John P. Hoehn, "Hedonic Analysis of Hazardous Waste Sites in the Presence of Other Urban Disamenities," *Environmental Science and Policy*, 2004, *7*, 499–508.

Deepwater Horizon Natural Resource Damage Assessment Trustees, "Deepwater Horizon oil spill: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement," Retrieved from http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan 2016.

Deryugina, Tatyana, Laura Kawano, and Steven Levitt, "The Economic Impact of Hurricane Katrina on its Victims: Evidence from Individual Tax Returns," Working Paper 20713, National Bureau of Economic Research November 2014.

Farber, Stephen, "Undesirable Facilities and Property Values: A Summary of Empirical Studies," *Ecological Economics*, 1998, *24*, 1–14.

Freeman III, A. Myrick, "Hedonic Prices, Property Values and Measuring Environmental Benefits: A Survey of the Issues," *The Scandinavian Journal of Economics*, 1979, *80* (2), 154–173.

_ , Joseph A. Herriges, and Catherine Kling, *The Measurement of Environmental and Resource Values: Theory and Methods*, 3rd ed., New York: Resources for the Future, 1993.

Gilbert, Daniel and Sarah Kent, "BP Agrees to Pay $18.7 Billion to Settle Deepwater Horizon Oil Spill Claims," *The Wall Street Journal*, July 2 2015.

Haninger, Kevin, Lala Ma, and Christopher Timmins, "The Value of the Brownfield Remediation," Working Paper 20296, National Bureau of Economic Research August 2014.

Ihlanfeldt, Keith and Laura O. Taylor, "Externality Effects of Small-Scale Hazardous Waste Sites: Evidence from Urban Commercial Property Markets," *Journal of Environmental Economics and Management*, 2004, *47*, 117 – 139.

Manson, Steven, Jonathan Schroeder, David Van Riper, and Steven Ruggles, "IPUMS National Historical Geographic Information System: Version 11.0 [Database]," 2016. (Accessed February 21, 2017).

MC-252 SCAT Program, "MC-252 SCAT Data QA/QC Final Report," Retrieved from https://gomex.erma.noaa.gov/layerfiles/19872/files/MC-2522014.

Muehlenbachs, Lucija, Elisheba Spiller, and Christopher Timmins, "The Housing Market Impacts of Shale Gas Development," *American Economic Review*, December 2015, *105* (12), 3633–59.

Ortega, Francesc and Süleyman Taşpinar, "Rising Sea Levels and Sinking Property Values: The Effects of Hurricane Sandy on New York's Housing Market," Discussion Paper 10374, The Institute for the Study of Labor (IZA) November 2016.

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy*, 1974, *82* (1), 34–55.

Siegel, Christy, Steven B Caudill, and Franklin G Mixon, "Clear Skies, Dark Waters: The Gulf Oil Spill and the Price of Coastal Condominiums in Alabama," *Economics and Business Letters*, 2013, *2* (2), 42–53.

Smithsonian Ocean Portal Team, *Ocean Acidification* NOAA 2016. (Accessed September 8, 2016).

United States Census Bureau / American FactFinder, "B25024: UNITS IN STRUCTURE," 2011-2015 American Community Survey 5-Year Estimates 2015. (Accessed October 12, 2017).

_ , "B25077: MEDIAN VALUE (DOLLARS)," 2011-2015 American Community Survey 5-Year Estimates 2015. (Accessed October 12, 2017).

Whitehead, John C, Tim Haab, James Sherry Larkin, John Loomis, Sergio Alvarez, Andrew Ropicki et al., "Lost Recreational Value from the Deepwater Horizon Oil Spill Using Revealed and Stated Preference Data," Technical Report 2016.

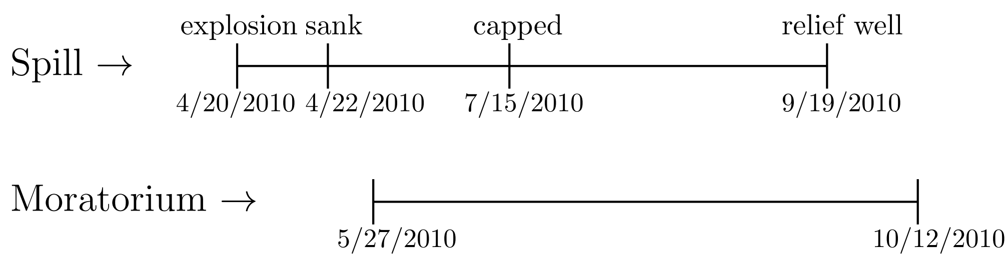
Winkler, Daniel T. and Bruce L. Gordon, "The Effect of the BP Oil Spill on Volume and Selling Prices of Oceanfront Condominiums.," *Land Economics*, 2013, *89* (4), 614 – 631.

A Appendix

A.1 Timeline

Figure 12 is a timeline of the events related to the BP oil spill. As our data report variation in the housing market at the annual level, we are unable to separately identify the effects of the spill itself from the moratorium on offshore, deepwater drilling issued in response to the BP oil spill.

Figure 12: Timing of the Oil Spill and Moratorium

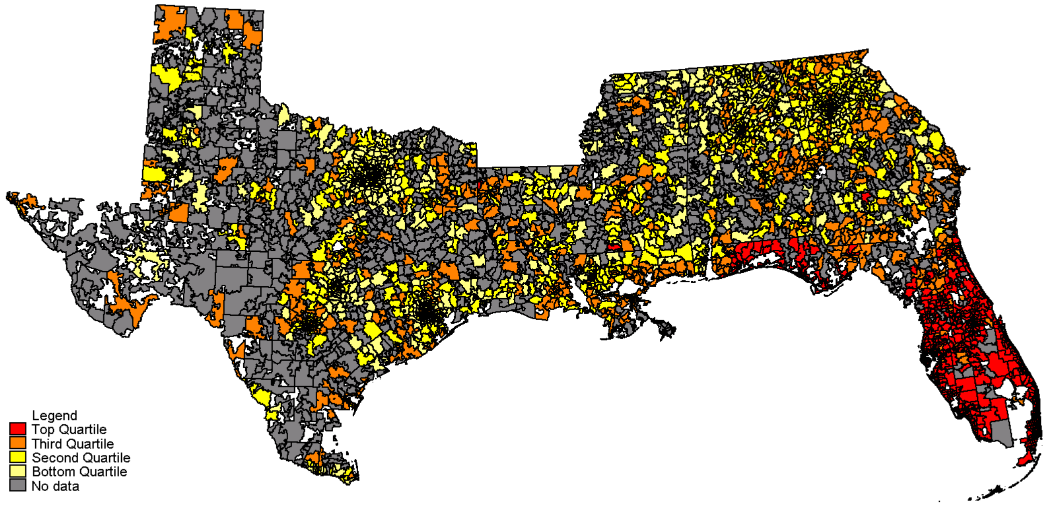


A.2 Spatial and Temporal Variation in the HPI

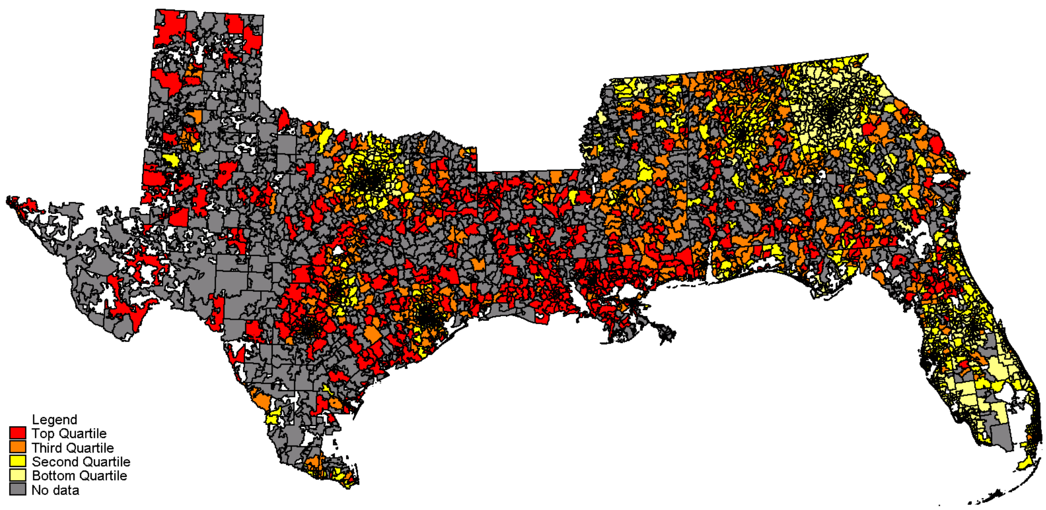
Figure 13 illustrates the spatial distribution of the HPI for three years that are representative of the overall time trend: 2005, 2010, and 2015.[43] The map in Subfigure 13(a) shades quartiles of the HPI different colors for the year 2005, five years before the spill. ZCTAs shaded in red represent the top quartile of the HPI with lighter shades (orange, yellow, and light yellow) representing successively lower quartiles. Subfigures 13(b) and 13(c) present the same information for the year of the spill (2010) and five years after the spill (2015). The figure shows substantial spatial clustering at both the state and sub-state levels that varies with time. To control for this spatio-temporal variation, we include both state-by-year fixed effects and county-specific quadratic time trends in our models.

[43] All three maps are relative to a common base year of 2003.

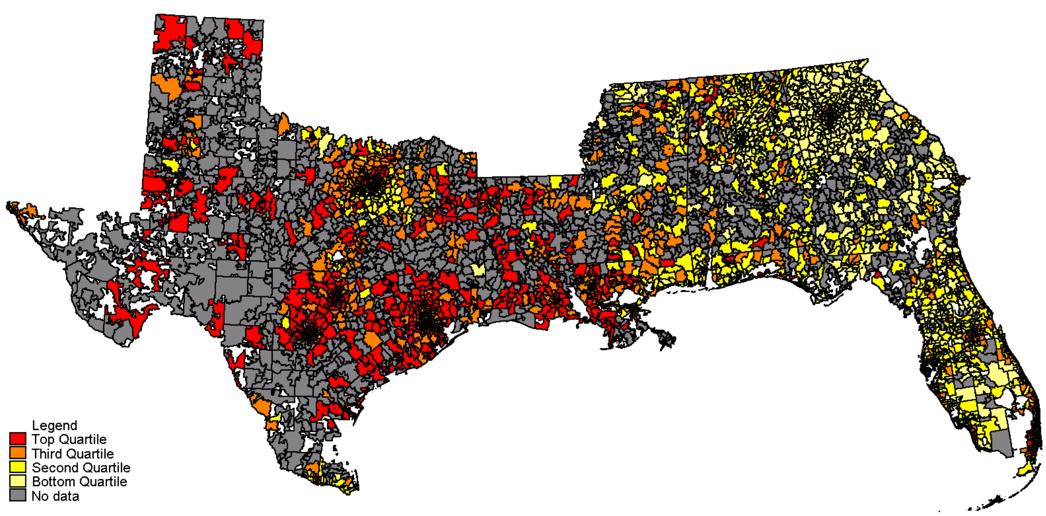
Figure 13: HPI Quartiles by Year



(a) 2005



(b) 2010



(c) 2015

A.3 Motivating DD Analyses

In this section, we provide estimates of the effect of the oil spill on single-family housing markets using multiple DD estimators that make use of alternative definitions of treatment and control groups. We proceed by defining these groups, using maps to give the reader a visual sense of their geographic compositions, and establishing the baseline effects of the spill with Wald estimators. Finally, we specify our DD regression equations, report estimates, and discuss the implications of our exploratory analyses for our primary analysis.

A.3.1 Additional DD Treatment and Control Groups

The effect of the oil spill on housing markets is the result of a combination of forces. By exploring additional treatment and control groups, we derive intuition as to which of these forces result in the observed effects and whether or not different control groups are adequate for identification of causal effects. In addition to the "Distance to Observed Oil" groups defined in Section 2.3 of the main text, we define two additional treatment and control groups. The names we assign to these alternative groups and their descriptions are:

1. **Contains Surveyed Coastline** - A natural definition of treatment and control groups is based on whether or not a given ZIP Code contains segments inspected by a SCAT team. In this definition, we consider all ZIP Codes containing SCAT inspected segments as the treatment group. As can be seen from the first column of Table 3, the sample contains 40 such ZIP Codes.[44] The control group is comprised of ZIP Codes that do not contain segments inspected for oil damage, but are less than 200 miles from the nearest surveyed segment. As Figure 3 illustrates, this is the approximate median distance from the surveyed coastline.[45] The number of ZIP Codes that fall into this category is reported in the seventh column of Table 3. Figure 14 displays maps of the treatment and control groups for both additional definitions outlined in this section, and Subfigure 14(a) is a map of those groups for the "Contains Surveyed Coastline" definition. In the map, the ZIP Codes in the control group are those in light red and the ZIP Codes in the treatment group are those in light gray. The map also indicates

[44] Table 3 is based on 2010 data for which HPI information is available. Over all years, there are 41, not 40, unique ZIP Codes that contain a SCAT inspected segment. One treatment ZIP Code is not included in the table because HPI information is not available for that location in 2010.

[45] Distance cutoffs are chosen to provide reasonable definitions of the given housing market for which there is never theoretical guidance, to produce adequate cell sizes, and to ensure the existence of parallel pre-trends required for identification. See Section 3.4 for a discussion of identification issues. We assess the robustness of our distance definitions for our main specification in Sections 3.3 and 3.6.

the intensity of oil observed along the coastline. Segments of the coastline in blue are those with no observed oil and those in red are zones with the heaviest oil damage.

2. **NOAA Coastal Definition** - The alternative treatment and control groups for this definition are suggested by the work of Aldy (2014) to estimate the labor market effects of the oil spill. Aldy uses as the treatment group all counties along the Gulf Coast that are defined by NOAA as "coastal counties" (see Figure 2 in Aldy, 2014). For the control group, Aldy uses all remaining counties in the five Gulf states. Hence we use all ZIP Codes located in NOAA defined Gulf Coastal counties as the treatment group and all remaining ZIP Codes in the Gulf states as the control group.[46] The map of these treatment and control groups can be found in Subfigure 14(b).

A.3.2 Additional Trend Analyses

Akin to Figure 5 based on our "Distance to Observed Oil" definition, Figure 15 contains plots of the unconditional average price index from 2000 to 2016 for our additional two treatment and control group definitions. The plots are similar to the one found in the main text, further indicating that there is substantial heterogeneity in the housing market crash experiences of Gulf coastal communities. These differences between our treatment and control groups confound causal estimation.

A.3.3 Wald Estimators

Before addressing the confounding effects in our unconditional trends, we seek to establish baseline effects of the BP spill for each of our three definitions. In Table 7, we present the most basic DD estimator of the effect of the oil spill on the housing markets. This table presents the average of the logarithm of the HPI for each of the three alternative treatment and control groups before and after the oil spill occurred in 2010. The pre-spill period covers the years 2005-2009, and the post period runs from 2011 to 2016.

The top panel, based on the contains surveyed coastline definitions, indicates that before the spill, the difference in the average house price index between the treatment and control groups is 13.0 percent. After the oil spill, this difference shrinks to 5.3 percent. Thus, the DD estimate of the causal effect of the oil spill on housing markets based on this treatment and control group definition is a decrease of 7.7 percent in the HPI. The middle panel for the alternative groups based on the distance to the inspected coastline presents a smaller

[46] To be consistent with Aldy's definition, we exclude Georgia from the control group.

estimate of a decrease of 1.5 percent, and the bottom panel based on the NOAA definition of Gulf Coastal ZIP Codes presents a moderate estimate of a decrease of 4.9 percent.

A.3.4 DD Regression Model Estimators

The Wald estimators in Table 7 provide some intuition on the effect of the oil spill on house prices, but they do not account for other factors that could potentially affect the results. For that reason, we turn to a DD regression analysis that allows us to obtain more precise estimates of the causal effect of the oil spill on housing markets. In addition, regression models allow us to cluster standard errors to account for serial correlation (Bertrand et al., 2004). We consider the following specification:

$$\ln(p_{it}) = \alpha_t + \gamma_i + \beta D_t G_i + X_{it}\delta + \varepsilon_{it}, \tag{4}$$

where $\ln(p_{it})$ is the natural logarithm of the house price index in ZIP Code i in year t, D_t is an indicator variable equal to 0 for years 2005-2009 and equal to 1 for years 2010-2016, G_i is an indicator variable equal to 0 if ZIP Code i is in the control group and equal to 1 if ZIP Code i is in the treatment group, X_{it} is a vector of potential controls, and the α_t and γ_i are year effects and ZIP Code fixed effects, respectively. The parameter of interest is β which can be interpreted as the DD estimator of the net effect of the spill on the housing market.

Table 8 presents the results from estimating specification (4) with and without controls. Columns (1), (3), and (5) present the DD estimators when we only include year effects and ZIP Code fixed effects for each of the alternative treatment and control groups. These estimates are a close regression analog to the estimates presented in Table 7. Since they do not control for any additional covariates, the estimates may reflect regional and local conditions that could have affected housing markets differently, especially during the crash. Columns (2), (4), and (6) present estimates from models that include linear and quadratic county-specific trends and state-year fixed effects. Using this more flexible specification, the results for the contains surveyed coastline treatment and control definition in Column (2) indicate that the effect of the oil spill on house prices was a statistically significant decrease of 3.54 percent. The other two alternative treatment and control groups yield estimates that are much smaller and not significantly different from zero.

The results of our exploratory regression analyses illuminate two important and intuitive facts that inform the specification of our primary empirical model. First, given our alternative definitions of treatment and control groups, the results from Table 8 suggest that the

Table 7: Average HPI Before & After the Oil Spill by Treatment & Control Group Definition

	Contains Surveyed Coastline		
	Control (A)	Treatment (B)	Difference (B) - (A)
Before 2010	5.273	5.403	0.130
	(0.011)	(0.046)	(0.047)
After 2010	5.180	5.233	0.053
	(0.010)	(0.042)	(0.043)
After-Before	-0.092	-0.170	-0.077
	(0.005)	(0.023)	(0.023)
	Distance to Observed Oil		
	Control (A)	Treatment (B)	Difference (B) - (A)
Before 2010	5.175	5.230	0.055
	(0.015)	(0.015)	(0.021)
After 2010	5.131	5.171	0.040
	(0.016)	(0.015)	(0.022)
After-Before	-0.044	-0.059	-0.015
	(0.009)	(0.006)	(0.011)
	NOAA Coastal Definition		
	Control (A)	Treatment (B)	Difference (B) - (A)
Before 2010	5.281	5.362	0.081
	(0.012)	(0.013)	(0.018)
After 2010	5.223	5.254	0.031
	(0.011)	(0.012)	(0.016)
After-Before	-0.058	-0.108	-0.049
	(0.005)	(0.006)	(0.008)

Note: The numbers in the table represent the mean of the natural logarithm of the house price index in the corresponding areas. Standard errors are shown in parentheses. House price indices for 2010 are not included in any of the calculations.

Table 8: DD Estimates with Alternative Control and Treatment Groups

	Contains Surveyed Coastline		Distance to Observed Oil		NOAA Coastal Definition	
	(1)	(2)	(3)	(4)	(5)	(6)
$D_t \times G_i$	-0.0775***	-0.0354***	-0.0139	0.00498	-0.0499***	0.00113
	(0.0238)	(0.0127)	(0.0113)	(0.00585)	(0.00820)	(0.00409)
Controls:						
ZIP Code effects	y	y	y	y	y	y
Year effects	y	y	y	y	y	y
County-spec. linear trend		y		y		y
County-spec. quadratic trend		y		y		y
State × year effects		y		y		y
No. of ZIP Codes in:						
Control group	1375	1375	477	477	1590	1590
Treatment group	41	41	434	434	940	940
Sample size	16,671	16,671	10,696	10,696	29,905	29,905
R^2	0.919	0.984	0.913	0.980	0.924	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

oil spill primarily had an effect on locations close to the coast. In the models with insignificant estimated effects reported in Columns (4) and (6), the treatment group includes many "inland" ZIP Codes that are not in direct contact with the coastline. Only the estimate in Column (2) is statistically significant. In that model, the treatment group only includes ZIP Codes that are in direct contact with the coastline. Taken together, this suggests a potentially localized effect. This is intuitive given both the nature of the oil damage caused by the spill and the size of our unit of observation. While the effects of the spill are certainly not limited to only markets on the coast, the direct effects of the spill are likely confined to waterfront properties and markets. Additionally, indirect effects are likely to decline with distance from the coast. Since ZIP Codes aggregate disparate waterfront and inland homes to begin with, treating non-coastal communities as treated reduces the power of our estimation.

Second, the decreases in the magnitude of the estimates of our coefficient of interest in all three specifications suggest that the housing market crash affects estimates of the effect of the spill and our controls are addressing at least some of this confounding factor. Failure to adequately control for the crash with an appropriate counterfactual, conditional on covariates, is likely to result in biased estimates. Given the sensitivity of our estimates to the inclusion of additional controls and the lack of a robust result across our models, we cannot rule out that we have not completely controlled for the effects of the housing market crash.[47] Again, this is an intuitive finding. Coastal real estate markets are likely to behave differently, particularly with regards to the housing market crash, than their inland neighbors. There are numerous factors that drive this difference. The most obvious of which is the high proportion of vacation homes along the coast.

A.4 DDD Treatment and Control Group Maps

Figure 16 contains maps that illustrate which ZIP Codes are defined as being part of each of our four DDD treatment and control groups. Subfigure 16(a) does so for the zero-mile

[47] We do not include a formal exposition of identification issues and an empirical analysis of the validity of our modeling assumptions in this appendix. We note, however, that event study analyses confirm our suspicion that the housing market crash confounds these DD estimates despite the included controls. We also perform additional, unreported exploratory analyses to rule out an alternative source of unobserved differences between our treatment and control groups: differences in local economies. To do so, we partition the dataset into regional subsections and estimate the model specified in Equation (4) on those sub-samples. Results of these analyses further support our finding that differential effects of the housing market crash are the primary threat to identification. The results of both the event studies and local market analyses are available from the authors by request.

coastal distance cutoff and the 125-mile treatment definition. Subfigure 16(b) uses the same 125-mile treatment definition and a five-mile coastal distance cutoff.

A.5 Event Study Estimates

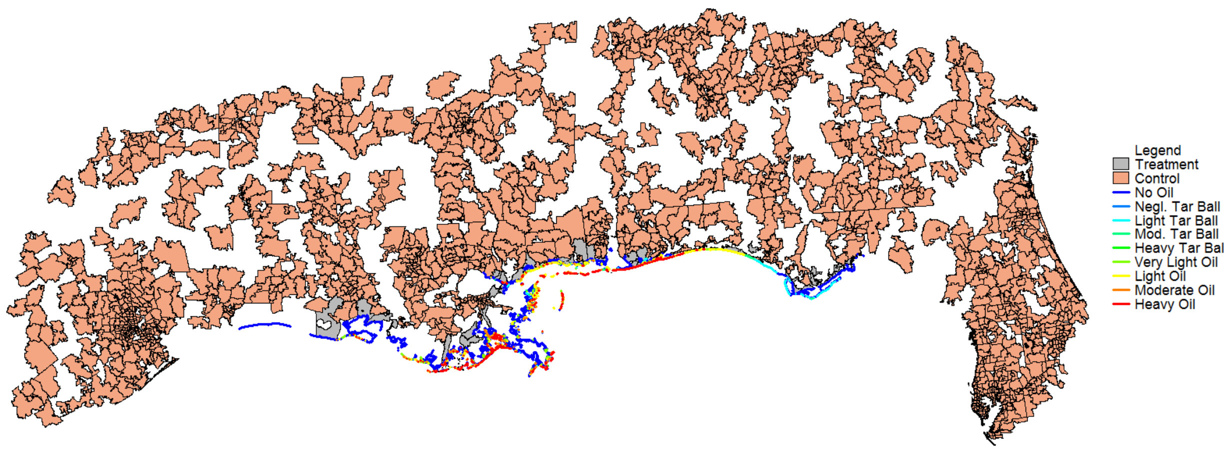
Table 9 contains estimates from our event study specification (Equation 2) for all combinations of our treatment and coastal distance definitions. This information is presented visually in the main text in Figure 7.

Table 9: DDD Event Study Estimates by Interior Treatment and Coastal Definition

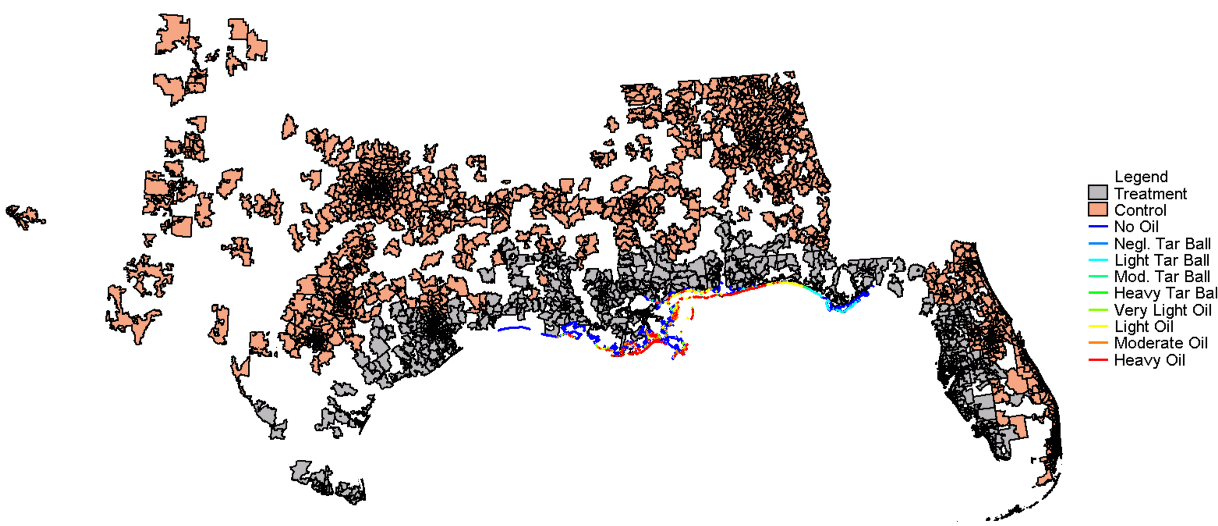
	100-Mile Interior Treatment Coastal Definition			125-Mile Interior Treatment Coastal Definition			150-Mile Interior Treatment Coastal Definition		
	0 mi	5 mi	10 mi	0 mi	5 mi	10 mi	0 mi	5 mi	10 mi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathbf{1}\{2005\} \times C_i \times G_i$	0.052**	0.034**	0.022*	0.041*	0.026*	0.015	0.028	0.020	0.012
	(0.022)	(0.016)	(0.012)	(0.022)	(0.015)	(0.012)	(0.019)	(0.013)	(0.011)
$\mathbf{1}\{2006\} \times C_i \times G_i$	0.026*	0.011	0.002	0.018	0.005	-0.001	0.008	0.002	-0.004
	(0.014)	(0.010)	(0.008)	(0.015)	(0.010)	(0.008)	(0.012)	(0.009)	(0.007)
$\mathbf{1}\{2007\} \times C_i \times G_i$	-0.002	-0.000	-0.006	-0.009	-0.005	-0.009	-0.010	-0.006	-0.012
	(0.014)	(0.010)	(0.008)	(0.014)	(0.010)	(0.008)	(0.012)	(0.009)	(0.007)
$\mathbf{1}\{2008\} \times C_i \times G_i$	-0.005	-0.002	-0.008	-0.012	-0.006	-0.010	-0.017**	-0.010	-0.013**
	(0.009)	(0.008)	(0.006)	(0.010)	(0.008)	(0.006)	(0.008)	(0.007)	(0.006)
$\mathbf{1}\{2009\} \times C_i \times G_i$	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
$\mathbf{1}\{2010\} \times C_i \times G_i$	-0.079***	-0.041***	-0.029***	-0.083***	-0.044***	-0.032***	-0.088***	-0.047***	-0.033***
	(0.013)	(0.010)	(0.008)	(0.013)	(0.010)	(0.008)	(0.013)	(0.009)	(0.008)
$\mathbf{1}\{2011\} \times C_i \times G_i$	-0.084***	-0.052***	-0.045***	-0.089***	-0.055***	-0.047***	-0.092***	-0.057***	-0.047***
	(0.016)	(0.011)	(0.009)	(0.016)	(0.010)	(0.009)	(0.014)	(0.010)	(0.009)
$\mathbf{1}\{2012\} \times C_i \times G_i$	-0.082***	-0.058***	-0.056***	-0.090***	-0.062***	-0.058***	-0.093***	-0.064***	-0.058***
	(0.016)	(0.011)	(0.010)	(0.016)	(0.011)	(0.010)	(0.015)	(0.010)	(0.009)
$\mathbf{1}\{2013\} \times C_i \times G_i$	-0.079***	-0.058***	-0.058***	-0.088***	-0.063***	-0.061***	-0.091***	-0.064***	-0.060***
	(0.016)	(0.012)	(0.011)	(0.016)	(0.011)	(0.011)	(0.015)	(0.011)	(0.010)
$\mathbf{1}\{2014\} \times C_i \times G_i$	-0.080***	-0.062***	-0.067***	-0.096***	-0.071***	-0.073***	-0.101***	-0.072***	-0.072***
	(0.018)	(0.014)	(0.015)	(0.022)	(0.015)	(0.014)	(0.019)	(0.014)	(0.013)
$\mathbf{1}\{2015\} \times C_i \times G_i$	-0.045**	-0.034**	-0.048***	-0.053***	-0.039**	-0.050***	-0.058***	-0.039***	-0.047***
	(0.019)	(0.016)	(0.018)	(0.018)	(0.016)	(0.016)	(0.016)	(0.014)	(0.014)
$\mathbf{1}\{2016\} \times C_i \times G_i$	-0.024	-0.010	-0.035	-0.033	-0.017	-0.035*	-0.039*	-0.016	-0.031*
	(0.023)	(0.020)	(0.021)	(0.023)	(0.019)	(0.020)	(0.020)	(0.017)	(0.017)

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state $\times$ year effects; and county-specific linear and quadratic trends.

Figure 14: Additional Treatment and Control Group Maps by Treatment & Control Group Definition

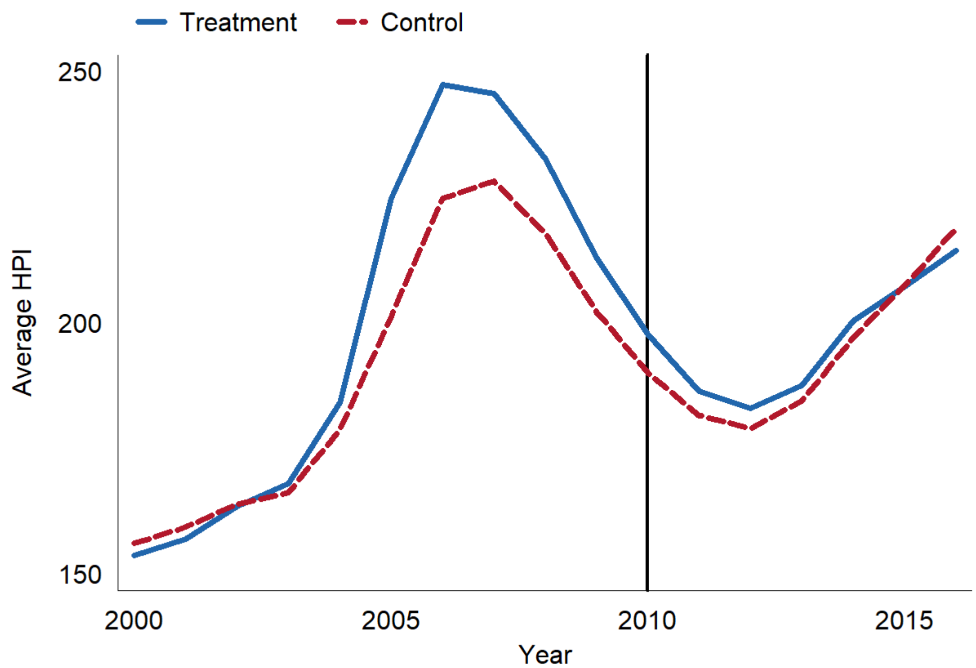


(a) Contains Surveyed Coastline Definition

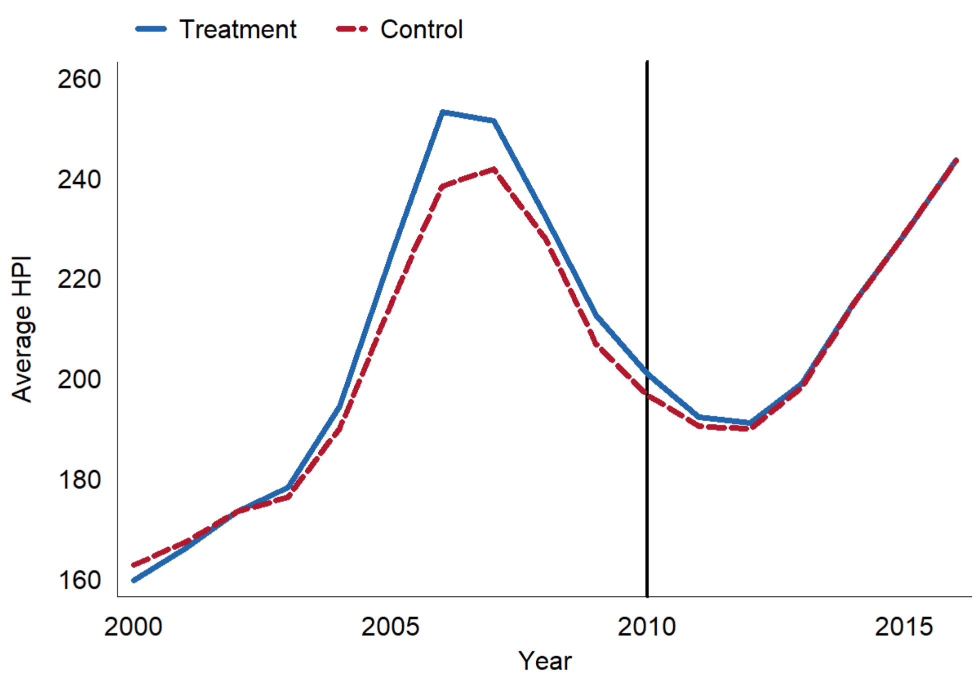


(b) NOAA Coastal Definition

Figure 15: Average HPI over Time by Treatment & Control Group Definition

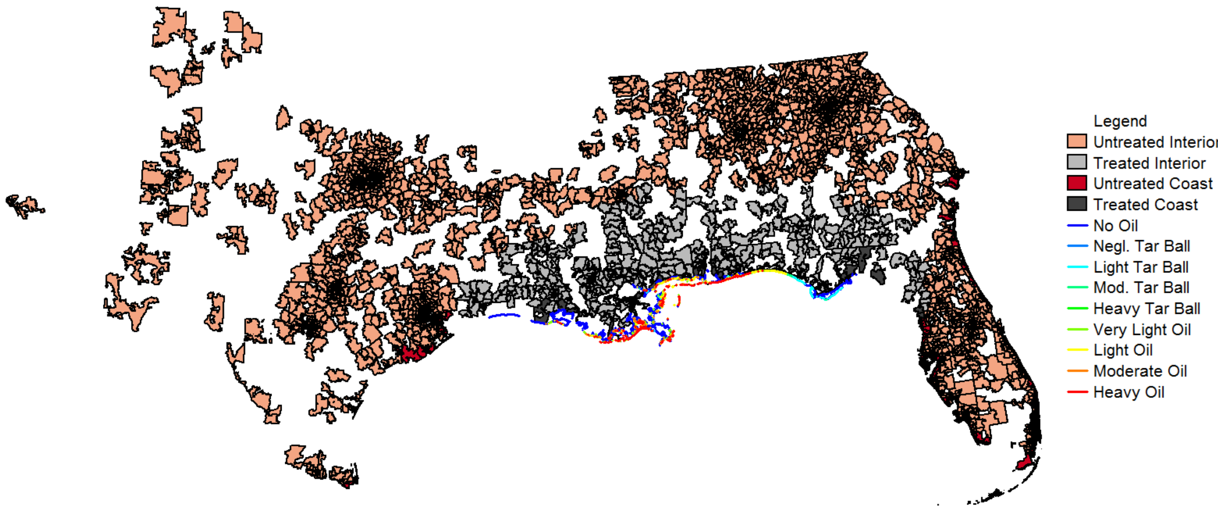


(a) Contains Surveyed Coastline Definition

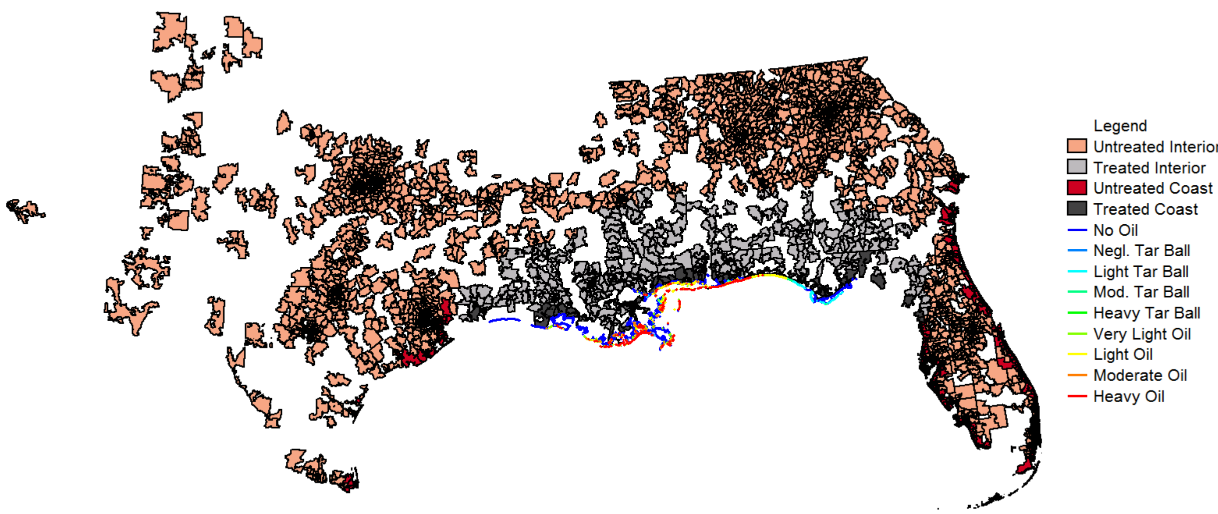


(b) NOAA Coastal Definition

Figure 16: Additional Treatment and Control Group Maps by Coastal and Interior



(a) Zero-Miles Coastal; 125-Miles Interior Treatment Definition



(b) Five-Miles Coastal; 125-Miles Interior Treatment Definition

A.6 Additional Spill Effect Estimates by Distance

Tables 10 and 11 contain DDD and event study estimates by coastal distance cutoff for the 100- and 150-mile interior treatment definitions, respectively.

Table 10: DDD Estimates by Coastal Definition Distance (100-Mile Interior)

	Coastal Definition Distance							
	0 mi	1 mi	3 mi	5 mi	10 mi	15 mi	20 mi	25 mi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Main Model Estimates								
$D_t \times G_i \times C_i$	-0.0808***	-0.0735***	-0.0616***	-0.0511***	-0.0429***	-0.0306***	-0.0228***	-0.0114
	(0.0155)	(0.0145)	(0.0121)	(0.0113)	(0.0107)	(0.00946)	(0.00865)	(0.00824)
Panel B: Event Study Estimates								
$\mathbf{1}\{2005\} \times C_i \times G_i$	0.0526**	0.0555***	0.0429**	0.0349**	0.0220*	0.0127	0.00576	-0.00650
	(0.0223)	(0.0209)	(0.0174)	(0.0160)	(0.0126)	(0.0113)	(0.0106)	(0.00922)
$\mathbf{1}\{2006\} \times C_i \times G_i$	0.0268*	0.0233*	0.0188	0.0117	0.00268	-0.000469	-0.00569	-0.0183***
	(0.0146)	(0.0140)	(0.0116)	(0.0108)	(0.00853)	(0.00773)	(0.00767)	(0.00659)
$\mathbf{1}\{2007\} \times C_i \times G_i$	-0.00247	0.000787	0.000375	-0.000779	-0.00666	-0.00926	-0.0132*	-0.0228***
	(0.0140)	(0.0132)	(0.0111)	(0.0106)	(0.00837)	(0.00744)	(0.00703)	(0.00646)
$\mathbf{1}\{2008\} \times C_i \times G_i$	-0.00594	-0.00480	-0.00511	-0.00270	-0.00830	-0.0105*	-0.0127**	-0.0180***
	(0.00964)	(0.00906)	(0.00765)	(0.00816)	(0.00685)	(0.00605)	(0.00541)	(0.00509)
$\mathbf{1}\{2009\} \times C_i \times G_i$	-	-	-	-	-	-	-	-
$\mathbf{1}\{2010\} \times C_i \times G_i$	-0.0794***	-0.0715***	-0.0518***	-0.0414***	-0.0298***	-0.0243***	-0.0212***	-0.0136*
	(0.0138)	(0.0129)	(0.0106)	(0.0105)	(0.00864)	(0.00836)	(0.00768)	(0.00745)
$\mathbf{1}\{2011\} \times C_i \times G_i$	-0.0843***	-0.0761***	-0.0627***	-0.0526***	-0.0452***	-0.0368***	-0.0309***	-0.0206***
	(0.0164)	(0.0152)	(0.0121)	(0.0112)	(0.00970)	(0.00899)	(0.00814)	(0.00781)
$\mathbf{1}\{2012\} \times C_i \times G_i$	-0.0824***	-0.0737***	-0.0666***	-0.0585***	-0.0567***	-0.0456***	-0.0378***	-0.0313***
	(0.0162)	(0.0153)	(0.0128)	(0.0117)	(0.0105)	(0.00941)	(0.00837)	(0.00826)
$\mathbf{1}\{2013\} \times C_i \times G_i$	-0.0796***	-0.0711***	-0.0668***	-0.0582***	-0.0587***	-0.0469***	-0.0394***	-0.0350***
	(0.0161)	(0.0154)	(0.0128)	(0.0120)	(0.0118)	(0.00996)	(0.00874)	(0.00882)
$\mathbf{1}\{2014\} \times C_i \times G_i$	-0.0804***	-0.0756***	-0.0699***	-0.0629***	-0.0671***	-0.0515***	-0.0418***	-0.0385***
	(0.0187)	(0.0175)	(0.0148)	(0.0149)	(0.0152)	(0.0119)	(0.0101)	(0.0102)
$\mathbf{1}\{2015\} \times C_i \times G_i$	-0.0459**	-0.0414**	-0.0409***	-0.0341**	-0.0487***	-0.0354***	-0.0292***	-0.0296***
	(0.0192)	(0.0181)	(0.0156)	(0.0168)	(0.0181)	(0.0133)	(0.0107)	(0.0112)
$\mathbf{1}\{2016\} \times C_i \times G_i$	-0.0245	-0.0125	-0.0171	-0.0105	-0.0355	-0.0193	-0.00841	-0.0118
	(0.0235)	(0.0226)	(0.0190)	(0.0208)	(0.0216)	(0.0154)	(0.0120)	(0.0129)
No. of ZIP Codes in:								
Control Coast	47	52	74	89	124	193	224	158
Treatment Coast	155	198	293	373	520	655	722	599
Sample Size	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602
R^2	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state × year effects; and county-specific linear and quadratic trends.

Table 11: DDD Estimates by Coastal Definition Distance (150-Mile Interior)

	Coastal Definition							
	0 mi	1 mi	3 mi	5 mi	10 mi	15 mi	20 mi	25 mi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Main Model Estimates								
$D_t \times G_i \times C_i$	-0.0824***	-0.0750***	-0.0645***	-0.0519***	-0.0417***	-0.0292***	-0.0244***	-0.0177**
	(0.0142)	(0.0132)	(0.0112)	(0.0102)	(0.00945)	(0.00877)	(0.00801)	(0.00777)
Panel B: Event Study Estimates								
$\mathbf{1}\{2005\} \times C_i \times G_i$	0.0289	0.0325*	0.0281*	0.0209	0.0126	0.00202	0.00216	-0.00291
	(0.0190)	(0.0181)	(0.0153)	(0.0139)	(0.0114)	(0.0108)	(0.0104)	(0.0101)
$\mathbf{1}\{2006\} \times C_i \times G_i$	0.00893	0.00702	0.00812	0.00238	-0.00468	-0.00924	-0.00981	-0.0173**
	(0.0129)	(0.0124)	(0.0105)	(0.00962)	(0.00793)	(0.00757)	(0.00752)	(0.00720)
$\mathbf{1}\{2007\} \times C_i \times G_i$	-0.0109	-0.00782	-0.00549	-0.00634	-0.0122	-0.0164**	-0.0173***	-0.0232***
	(0.0121)	(0.0116)	(0.00995)	(0.00941)	(0.00756)	(0.00693)	(0.00662)	(0.00640)
$\mathbf{1}\{2008\} \times C_i \times G_i$	-0.0172**	-0.0155*	-0.0136*	-0.0105	-0.0137**	-0.0159***	-0.0170***	-0.0199***
	(0.00874)	(0.00833)	(0.00714)	(0.00741)	(0.00616)	(0.00547)	(0.00497)	(0.00475)
$\mathbf{1}\{2009\} \times C_i \times G_i$	-	-	-	-	-	-	-	-
$\mathbf{1}\{2010\} \times C_i \times G_i$	-0.0887***	-0.0802***	-0.0606***	-0.0477***	-0.0336***	-0.0268***	-0.0248***	-0.0207***
	(0.0134)	(0.0125)	(0.0103)	(0.00994)	(0.00824)	(0.00809)	(0.00738)	(0.00731)
$\mathbf{1}\{2011\} \times C_i \times G_i$	-0.0922***	-0.0836***	-0.0705***	-0.0577***	-0.0473***	-0.0368***	-0.0337***	-0.0270***
	(0.0148)	(0.0137)	(0.0113)	(0.0103)	(0.00902)	(0.00865)	(0.00780)	(0.00758)
$\mathbf{1}\{2012\} \times C_i \times G_i$	-0.0939***	-0.0846***	-0.0758***	-0.0645***	-0.0582***	-0.0475***	-0.0427***	-0.0392***
	(0.0151)	(0.0142)	(0.0120)	(0.0108)	(0.00949)	(0.00891)	(0.00794)	(0.00783)
$\mathbf{1}\{2013\} \times C_i \times G_i$	-0.0919***	-0.0827***	-0.0757***	-0.0644***	-0.0603***	-0.0504***	-0.0455***	-0.0435***
	(0.0152)	(0.0144)	(0.0121)	(0.0110)	(0.0103)	(0.00923)	(0.00822)	(0.00811)
$\mathbf{1}\{2014\} \times C_i \times G_i$	-0.101***	-0.0944***	-0.0840***	-0.0728***	-0.0728***	-0.0585***	-0.0498***	-0.0476***
	(0.0194)	(0.0182)	(0.0151)	(0.0141)	(0.0131)	(0.0109)	(0.00949)	(0.00930)
$\mathbf{1}\{2015\} \times C_i \times G_i$	-0.0589***	-0.0531***	-0.0485***	-0.0392***	-0.0472***	-0.0374***	-0.0304***	-0.0299***
	(0.0167)	(0.0157)	(0.0136)	(0.0140)	(0.0142)	(0.0113)	(0.00971)	(0.00994)
$\mathbf{1}\{2016\} \times C_i \times G_i$	-0.0390*	-0.0271	-0.0255	-0.0164	-0.0312*	-0.0193	-0.00620	-0.00788
	(0.0201)	(0.0194)	(0.0166)	(0.0170)	(0.0170)	(0.0131)	(0.0112)	(0.0117)
No. of ZIP Codes in:								
Control Coast	58	63	86	103	145	183	223	259
Treatment Coast	144	187	281	359	499	574	625	687
Sample Size	35,602	35,602	35,602	35,602	35,602	35,602	35,602	35,602
R^2	0.986	0.986	0.986	0.986	0.986	0.986	0.986	0.986

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state × year effects; and county-specific linear and quadratic trends.

A.7 Estimates by Treatment and Coastal Definition Distances

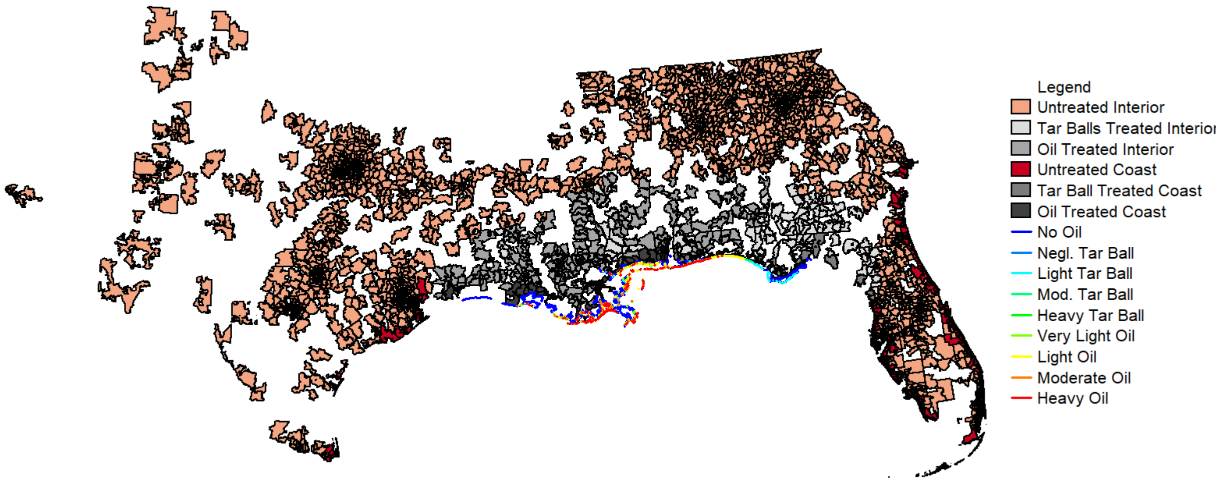
Table 12 reports estimates of the DDD estimates of the effects of the oil spill by various definitions of treatment and coastal groups.

Table 12: DDD Estimates by Interior Treatment and Coastal Definition Distances

		Coastal Definition									
		0 mi	1 mi	2 mi	3 mi	4 mi	5 mi	10 mi	15 mi	20 mi	25 mi
Interior Treatment Definition	25 mi	-0.0781***	-0.0706***	-0.0597***	-0.0594***	-0.0541***	-0.0506***	-0.0460***	-0.0315***	-0.0293**	-0.00784
		(0.0158)	(0.0150)	(0.0132)	(0.0128)	(0.0123)	(0.0125)	(0.0127)	(0.0106)	(0.0124)	(0.0189)
	50 mi	-0.0775***	-0.0702***	-0.0596***	-0.0580***	-0.0522***	-0.0480***	-0.0414***	-0.0271***	-0.0203**	-0.00574
		(0.0156)	(0.0147)	(0.0129)	(0.0122)	(0.0116)	(0.0116)	(0.0113)	(0.0100)	(0.00972)	(0.00946)
	75 mi	-0.0783***	-0.0709***	-0.0603***	-0.0586***	-0.0528***	-0.0485***	-0.0398***	-0.0259***	-0.0200**	-0.00851
		(0.0155)	(0.0146)	(0.0128)	(0.0121)	(0.0115)	(0.0114)	(0.0109)	(0.00969)	(0.00902)	(0.00866)
	100 mi	-0.0808***	-0.0735***	-0.0630***	-0.0616***	-0.0552***	-0.0511***	-0.0429***	-0.0306***	-0.0228***	-0.0114
		(0.0155)	(0.0145)	(0.0127)	(0.0121)	(0.0114)	(0.0113)	(0.0107)	(0.00946)	(0.00865)	(0.00824)
	125 mi	-0.0826***	-0.0753***	-0.0648***	-0.0631***	-0.0568***	-0.0521***	-0.0437***	-0.0316***	-0.0234***	-0.0145*
		(0.0153)	(0.0143)	(0.0126)	(0.0119)	(0.0112)	(0.0110)	(0.0102)	(0.00918)	(0.00841)	(0.00810)
	150 mi	-0.0824***	-0.0750***	-0.0648***	-0.0645***	-0.0575***	-0.0519***	-0.0417***	-0.0292***	-0.0244***	-0.0177**
		(0.0142)	(0.0132)	(0.0118)	(0.0112)	(0.0105)	(0.0102)	(0.00945)	(0.00877)	(0.00801)	(0.00777)
	175 mi	-0.0859***	-0.0763***	-0.0728***	-0.0641***	-0.0579***	-0.0513***	-0.0499***	-0.0472***	-0.0399***	-0.0354***
		(0.0139)	(0.0124)	(0.0110)	(0.0104)	(0.00987)	(0.00959)	(0.00910)	(0.00899)	(0.00795)	(0.00776)
	200 mi	-0.0768***	-0.0676***	-0.0634***	-0.0577***	-0.0519***	-0.0500***	-0.0503***	-0.0555***	-0.0513***	-0.0338***
		(0.0161)	(0.0142)	(0.0125)	(0.0116)	(0.0110)	(0.0103)	(0.00933)	(0.00971)	(0.00846)	(0.00840)

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state × year effects; and county-specific linear and quadratic trends.

Figure 17: Treatment and Control Groups by Intensity of Damage (Five-Mile Coastal; 125-Mile Interior)



A.8 Intensity of Damage Treatment Map

Figure 17 shows which ZIP Codes are defined as treated based on their proximity to the nearest aggregate oil damage category (tar balls or oil). The map uses the five-mile coastal definition and the 125-mile interior treatment definition.[48]

A.9 Intensity of Damage Event Study Estimates

Table 13 contains event study estimates of the effects of tar ball and oil damage on housing markets by year. Columns report tar ball and oil estimates for different coastal distance definitions. All estimates are based on the 125-mile interior treatment definition.

[48] Maps for alternative distance cutoffs are available from the authors by request.

Table 13: Damage Intensity DDD Event Study Estimates by Coastal Definition Distance (125-Mile Interior)

	Zero-Mile Coastal Definition		Five-Mile Coastal Definition		Ten-Mile Coastal Definition	
	Tar Ball	Oil	Tar Ball	Oil	Tar Ball	Oil
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathbf{1}\{2005\} \times C_i \times G_i$	0.0501	0.0357	0.00748	0.0335*	-0.0194	0.0346**
	(0.0446)	(0.0260)	(0.0257)	(0.0192)	(0.0203)	(0.0160)
$\mathbf{1}\{2006\} \times C_i \times G_i$	-0.0261	0.0392**	-0.0404**	0.0280**	-0.0445***	0.0233**
	(0.0267)	(0.0164)	(0.0180)	(0.0124)	(0.0151)	(0.0102)
$\mathbf{1}\{2007\} \times C_i \times G_i$	-0.0494**	0.0109	-0.0390**	0.0119	-0.0347**	0.00493
	(0.0234)	(0.0159)	(0.0178)	(0.0122)	(0.0140)	(0.00994)
$\mathbf{1}\{2008\} \times C_i \times G_i$	-0.0457***	0.00564	-0.0257**	0.00356	-0.0206*	-0.00392
	(0.0159)	(0.0115)	(0.0121)	(0.0104)	(0.0106)	(0.00854)
$\mathbf{1}\{2009\} \times C_i \times G_i$	-	-	-	-	-	-
$\mathbf{1}\{2010\} \times C_i \times G_i$	-0.0840***	-0.0817***	-0.0616***	-0.0350***	-0.0564***	-0.0195**
	(0.0193)	(0.0153)	(0.0152)	(0.0117)	(0.0122)	(0.00970)
$\mathbf{1}\{2011\} \times C_i \times G_i$	-0.0835***	-0.0908***	-0.0713***	-0.0471***	-0.0754***	-0.0331***
	(0.0213)	(0.0193)	(0.0153)	(0.0128)	(0.0133)	(0.0109)
$\mathbf{1}\{2012\} \times C_i \times G_i$	-0.0884***	-0.0904***	-0.0868***	-0.0507***	-0.0910***	-0.0432***
	(0.0233)	(0.0188)	(0.0171)	(0.0128)	(0.0150)	(0.0111)
$\mathbf{1}\{2013\} \times C_i \times G_i$	-0.0824***	-0.0902***	-0.0868***	-0.0527***	-0.0980***	-0.0451***
	(0.0265)	(0.0183)	(0.0179)	(0.0129)	(0.0175)	(0.0117)
$\mathbf{1}\{2014\} \times C_i \times G_i$	-0.112**	-0.0872***	-0.111***	-0.0533***	-0.125***	-0.0481***
	(0.0454)	(0.0207)	(0.0293)	(0.0149)	(0.0258)	(0.0140)
$\mathbf{1}\{2015\} \times C_i \times G_i$	-0.0569**	-0.0490**	-0.0859***	-0.0180	-0.116***	-0.0196
	(0.0251)	(0.0217)	(0.0255)	(0.0166)	(0.0263)	(0.0167)
$\mathbf{1}\{2016\} \times C_i \times G_i$	-0.0353	-0.0296	-0.0705**	0.00597	-0.116***	0.00114
	(0.0397)	(0.0260)	(0.0346)	(0.0201)	(0.0347)	(0.0197)

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state $\times$ year effects; and county-specific linear and quadratic trends.

A.10 Intensity Estimates by Treatment and Coastal Definition Distances

Table 14 reports estimates of the DDD estimates of the effects of the oil spill by intensity of oil damage by various definitions of treatment and coastal groups.

Table 14: Damage Intensity DDD Estimates by Treatment and Coastal Definition Distances

Interior Treatment Definition		Coastal Definition 0 mi	1 mi	2 mi	3 mi	4 mi	5 mi	10 mi	15 mi	20 mi	25 mi
25 mi	Tar Balls	-0.0206	-0.0157	-0.00861	-0.0143	-0.0115	-0.0247	-0.0236	-0.0565	-0.228***	
		(0.0237)	(0.0234)	(0.0216)	(0.0204)	(0.0203)	(0.0222)	(0.0278)	(0.0456)	(0.0158)	
	Heavy Oil	-0.0981***	-0.0911***	-0.0787***	-0.0745***	-0.0674***	-0.0576***	-0.0429***	-0.0235**	-0.0195	
		(0.0181)	(0.0170)	(0.0151)	(0.0145)	(0.0143)	(0.0141)	(0.0134)	(0.0116)	(0.0132)	
50 mi	Tar Balls	-0.0368*	-0.0320	-0.0259	-0.0338*	-0.0330*	-0.0432**	-0.0541***	-0.0677***	-0.0611***	-0.0439**
		(0.0221)	(0.0217)	(0.0201)	(0.0180)	(0.0171)	(0.0187)	(0.0209)	(0.0207)	(0.0226)	(0.0207)
	Heavy Oil	-0.0927***	-0.0847***	-0.0718***	-0.0666***	-0.0591***	-0.0494***	-0.0347***	-0.0151	-0.00827	0.00585
		(0.0177)	(0.0165)	(0.0144)	(0.0136)	(0.0133)	(0.0128)	(0.0118)	(0.0107)	(0.0102)	(0.0104)
75 mi	Tar Balls	-0.0435**	-0.0386*	-0.0328*	-0.0411**	-0.0402**	-0.0494***	-0.0554***	-0.0633***	-0.0570***	-0.0377**
		(0.0216)	(0.0212)	(0.0195)	(0.0168)	(0.0158)	(0.0173)	(0.0184)	(0.0172)	(0.0182)	(0.0162)
	Heavy Oil	-0.0908***	-0.0825***	-0.0697***	-0.0647***	-0.0573***	-0.0478***	-0.0330***	-0.0147	-0.00937	0.00161
		(0.0176)	(0.0164)	(0.0142)	(0.0135)	(0.0131)	(0.0127)	(0.0116)	(0.0106)	(0.00971)	(0.00952)
100 mi	Tar Balls	-0.0511**	-0.0462**	-0.0406**	-0.0502***	-0.0469***	-0.0556***	-0.0640***	-0.0713***	-0.0650***	-0.0496***
		(0.0212)	(0.0208)	(0.0190)	(0.0160)	(0.0150)	(0.0164)	(0.0170)	(0.0157)	(0.0162)	(0.0146)
	Heavy Oil	-0.0910***	-0.0827***	-0.0703***	-0.0657***	-0.0584***	-0.0492***	-0.0347***	-0.0177*	-0.00968	0.00218
		(0.0175)	(0.0163)	(0.0141)	(0.0134)	(0.0131)	(0.0126)	(0.0114)	(0.0104)	(0.00932)	(0.00901)
125 mi	Tar Balls	-0.0588***	-0.0539***	-0.0479***	-0.0551***	-0.0518***	-0.0588***	-0.0642***	-0.0670***	-0.0620***	-0.0491***
		(0.0204)	(0.0199)	(0.0183)	(0.0156)	(0.0141)	(0.0154)	(0.0153)	(0.0143)	(0.0148)	(0.0134)
	Heavy Oil	-0.0919***	-0.0833***	-0.0708***	-0.0662***	-0.0590***	-0.0492***	-0.0349***	-0.0188*	-0.0108	-0.00149
		(0.0175)	(0.0163)	(0.0141)	(0.0134)	(0.0130)	(0.0124)	(0.0111)	(0.0102)	(0.00920)	(0.00898)
150 mi	Tar Balls	-0.0641***	-0.0587***	-0.0513***	-0.0595***	-0.0545***	-0.0583***	-0.0552***	-0.0525***	-0.0539***	-0.0446***
		(0.0170)	(0.0163)	(0.0153)	(0.0138)	(0.0128)	(0.0135)	(0.0130)	(0.0126)	(0.0125)	(0.0116)
	Heavy Oil	-0.0924***	-0.0835***	-0.0713***	-0.0670***	-0.0592***	-0.0484***	-0.0336***	-0.0175*	-0.0114	-0.00363
		(0.0167)	(0.0155)	(0.0135)	(0.0129)	(0.0124)	(0.0117)	(0.0107)	(0.0101)	(0.00910)	(0.00895)
175 mi	Tar Balls	-0.0693***	-0.0622***	-0.0680***	-0.0620***	-0.0568***	-0.0529***	-0.0552***	-0.0526***	-0.0476***	-0.0470***
		(0.0165)	(0.0145)	(0.0133)	(0.0124)	(0.0118)	(0.0119)	(0.0112)	(0.0114)	(0.0106)	(0.0103)
	Heavy Oil	-0.0997***	-0.0900***	-0.0795***	-0.0706***	-0.0642***	-0.0550***	-0.0536***	-0.0514***	-0.0431***	-0.0344***
		(0.0158)	(0.0147)	(0.0130)	(0.0124)	(0.0118)	(0.0111)	(0.0105)	(0.0107)	(0.00942)	(0.00930)
200 mi	Tar Balls	-0.0516***	-0.0449***	-0.0454***	-0.0430***	-0.0386***	-0.0401***	-0.0440***	-0.0503***	-0.0492***	-0.0411***
		(0.0182)	(0.0161)	(0.0147)	(0.0137)	(0.0127)	(0.0121)	(0.0111)	(0.0118)	(0.0102)	(0.00998)
	Heavy Oil	-0.114***	-0.101***	-0.0889***	-0.0791***	-0.0719***	-0.0640***	-0.0605***	-0.0644***	-0.0574***	-0.0306***
		(0.0173)	(0.0156)	(0.0137)	(0.0129)	(0.0124)	(0.0116)	(0.0109)	(0.0116)	(0.0105)	(0.0108)

Note: Standard errors in parentheses are clustered at the ZIP Code level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
All models contain ZIP Code, year, and state × year effects; and county-specific linear and quadratic trends.