House Prices and Septic Tanks: An Examination of Miami-Dade County*
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August 20, 2024

Abstract

Septic Systems in low-lying coastal areas provide a unique opportunity to identify a clear, present, and increasingly relevant environmental threat and test whether the risk is internalized in house prices. Using data on the roughly 120,000 septic tanks in Miami-Dade County and residential transactions from 2002 to 2022, we find a significant and positive association between house prices and the presence of septic tanks that is inconsistent with market participants and property values internalizing the public health and environmental threat they pose. Instead, the value of an installed septic system and the corresponding reduction in operating and maintenance costs are associated with a premium of 3.1%. The findings complement current policy discussions, highlighting a unique setting for studying climate-related risks where the public and property owners' interests are not aligned.

JEL Classifications: Q51; Q53; Q54; R11
Keywords: Hedonic property model; Risk perceptions; Cost-benefit analysis

*We thank ...

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1 Introduction

Sea-level rise compromises low-lying septic tank systems, especially in coastal areas, posing a threat to public health, potable water, and the environment (Mihaly (2018), Cooper et al. (2016), and Mitchell et al. (2021)). It is estimated that 20% of households in the US are not connected to a sewer system and instead use onsite wastewater treatment systems (Hernandez and Pierce (2023)). Many of these are located in coastal areas and were installed assuming groundwater levels that did not account for sea-level rise. In Florida alone, there are an estimated 2.7 million septic systems (Flanagan et al. (2020)).

In Miami-Dade County, the roughly 120,000 septic systems in use pose a significant risk to the public and environment given the area's low elevation, interconnected groundwater and potable water, and vulnerability of vital local ecosystems like Biscayne Bay, which is not just important to the local environment but for recreation and the economic benefit it provides as well. Miami-Dade County estimates that, depending on conditions, 56% (58,349 parcels) of existing septic tank systems are periodically compromised.[1] Mitigation and remediation estimates range from $3.5 to $5 billion in Miami-Dade County alone.[2]

Septic tank systems offer a unique setting for studying the internalization of climate risk, in this case, sea-level rise and property markets, for a few reasons. First, septic tank systems are a property-level characteristic that captures a property's sensitivity to and contribution to climate risk. The within-market variation of septic status overcomes spatial correlation concerns in studies where the threat or risk applies to an area (i.e., floods, wildfires, or hurricanes). In Miami-Dade County, septic tank properties are co-mingled with connected properties because the decision and investment to connect to the sewer historically have been made at the property level on an ad-hoc basis.[3] This allows for comparing properties within the same market simultaneously that differ in terms of climate risk exposure.

Second, while septic tank systems increase a property's sensitivity and exposure to climate risk, the concern is not unidirectional. Studies on climate risk focus on the first-order threat to properties, markets, and stakeholders as the primary concern. The tendency is to identify a climate

[1] Septic Systems Vulnerable to sea-level rise, *Miami-Dade County RER-WASD-DOH* (November 2018).

[2] Alex Harris, "A $3 Billion problem: Miami-Dade's septic tanks are already failing due to sea rise," Miami Herald, January 14, 2019.

[3] Figure A1 displays the density of Septic Tank Systems across Miami-Dade County.

risk factor that, when it differentially impacts properties, allows researchers to identify an average treatment effect on the treated by comparing and contrasting treated properties from a control group. For example, does the price of a property located in a flood zone capitalize the flood risk? The concern with septic tank systems is not limited to the increased threat and sensitivity of these properties to sea-level rise but includes the second-order threat they pose to public health and the environment because of sea-level rise. Amongst the studies concerning the evolving preferences of market participants to internalize climate risk, we are unaware of any that concern property owners and market prices internalizing the threat of a climate risk externality and private property. The septic tank systems we consider are privately owned and operated.

Third, septic tank systems are unique in that while the threat to health and the environment is primarily public, there are private benefits. Properties with working septic systems benefit from low operating and maintenance costs and shield property owners from increasing wastewater rates. If and when a property owner wants to connect, conditional on the ability to do so (available sewer abutting/lateral), they incur the cost of properly abandoning their septic system and the costs involved in connecting to the sewer. The question of how market participants consider the perceived risk versus economic benefits of septic systems is an empirical one.

In this paper, we test for an association between the presence and use of septic tank systems in Miami-Dade County and whether their health/environmental risk gets capitalized in house prices. Using transaction-level data from Miami-Dade County and merging it with parcel-level septic system data from Miami-Dade County's utilities, Department of Health (DOH), and Regulation and Economic Resources, Division of Environmental Resource Management (RER/DERM), results in a sample of residential property transactions with and without a septic system for Miami-Dade County from 2002 through 2022. Using a difference-in-differences hedonic model of house prices, we test for an association between property values and (1) the presence of a septic tank, (2) variation in treatment by municipalities, time period, and market segment by price, (3) interaction of septic systems and water status (i.e., municipal water or well water), (4) changes in disclosure requirements (5) sewer abutment/notice of required connection (NORC), and (6) salience of major weather events to highlight the risks of septic systems.

After controlling for property characteristics, ZIP code, and sale-year-month fixed effects, the presence of a septic system is associated with a premium of 3.1%, which is economically and statistically at the 1% level. The positive and significant price premium holds across municipalities, time periods, property value segments, and changes that require disclosing septic tank status to prospective buyers. The sign of the price effect flips when a well is present, the property abuts a sewer or receives a NORC, and in the post-period of major weather events. The evidence is consistent with prices capitalizing the cost-savings of an operating septic system while being sensitive to increases in perceived risk (i.e., well-water, weather events) or the likelihood of having to incur costs of converting from septic to sewer (i.e., abutting/NORC).

We add to the literature on environmental amenities and disamenities in property markets and specifically to studies relating the risk of sea-level rise to property markets (i.e., information availability, salience of the threat, and required disclosures). Studies find that residential and commercial property markets increasingly internalize the direct and indirect costs related to climate risk. Commonly focused on flooding, there is consistent evidence that properties sensitive to flooding and sea-level rise transact at a discount.[4] Findings from looking at septic tank systems resemble Bin and Kruse (2006) that find price discounts from additional flood risk counterbalanced by the premium to be close to the coast. Although, in this study, the benefit is reduced user cost, the risk is public, and market participants can express preferences for septic tank status within the property market.

We highlight a unique setting for studying climate-related risks where the public and property owners are not aligned and contribute substantively to the dialogue around the mitigation and remediation of septic tank risk. To understand competing private and public interests, a fundamental understanding of market participants, the incentives they face, and an assessment of the cost-benefit analysis and economic contribution of septic tanks to property values is necessary.

The following section summarizes the issue and threat of septic tanks and relevant literature. In the third and fourth sections, we describe the data, empirical methods, and analysis to explore the association between house prices and septic tanks. Lastly, a concluding section covers the next steps and the importance of incorporating the economic motivations of market participants in similar discussions pertaining to climate-related risks.

[4] For examples, by property market: Carteret County, North Carolina (Bin et al. (2008)), Savannah, Georgia (Beck and Lin (2020)), the residential market generally (Bernstein et al. (2019)), or commercial real estate market (Addoum et al. (2023)).

2 Background

Installing a septic system is expensive, but it is a necessary condition for occupancy in the absence of sewer access. The cost of a brand-new septic tank system and drain field will depend on the type of the system and the size, but it can cost from $10,000 to $25,000. The return on that investment is twofold. First, the septic system is an amenity consumed by occupying and using the property, and second, the benefits afforded to owners with a septic system versus those connected to sewer. Once installed, the septic tank benefits the property owner by being cheaper to operate than what they would be charged hooked up to the sewer line.

A well-constructed and well-maintained septic system may last 50 years.[5] Over the life of that system, it will cost between $250 to $500 every three to five years to service. Which is significantly cheaper compared to the median residential sewer fee from 2023 of $57.20 per month ($686 per year) with the Miami-Dade Water and Sewer Department (WASD).[6] And from 2023 to 2024, the wholesale sewer rates increased by 5.32% to a projected $722 wastewater bill for the median residence.[7] Therefore, septic systems are costly to install but are cheaper to operate and shield owners from changes in wastewater utility rates.

Converting from septic to sewer is expensive, and the property owner bears the cost ranging from $7,500 to $40,000 depending on the ease and proximity of the public sewer hook-up.[8] Then, there is the additional cost to abandon and remediate their current septic tank system. For properties with working septic systems to incur the cost and convert to sewer may not be appealing.

Sea-level rise threatens to compromise septic tank systems in coastal and low-lying areas.[9] A properly functioning system releases the wastewater into a drain field where the percolation of the wastewater through a layer of dry soil is crucial to the purification process. When groundwater is too high, and the wastewater is not filtered sufficiently, the contaminated water ends up in the groundwater, entering the aquifer and contaminating drinking and coastal waters. Compromised and failing septic systems contribute to outbreaks of waterborne diseases, algae blooms, seagrass

[5] https://www.epa.gov/septic/frequent-questions-septic-systems

[6] WASD 2023 Rates, https://www.miamidade.gov/water/library/fees/2023-rates.pdf, Accessed (5/6/2024).

[7] https://www.miamibeachfl.gov/city-hall/public-works/utility-rates/

[8] Alex Harris and Adriana Brasileiro, "Miami-Dade's septic tank fix could cost taxpayers $4 billion – and homeowners thousands," Miami Herald, December 11, 2020.

[9] NOAA sensors in Virginia Key estimate the water level is rising 3.16 millimeters/year for Miami-Dade County (1.04 feet per 100 years). NOAA, "Tides and Currents," https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8723214.

dieoffs, and fish kills (Havens (2018)).

The threat to public health and the environment is well-documented. For example, Mitchell et al. (2021) highlights the impact of sea level rise on the performance of onsite wastewater treatment systems in rural Virginia, while Cooper et al. (2016) and Mihaly (2018) assess the risk to septic tank systems in the northeast. Locally, the topic is often discussed in the media, and reports are disseminated by Miami-Dade County on the issue.

Considering septic tank systems as a source of local pollution fits into the literature relating environmental disamenities to property values. The negative pricing effect of nearby environmental contaminants or risks is well-documented. Generally, findings are proportional to the severity and proximity of the threat, whether it is nearby landfills (Ready (2010)), underground storage tanks for petroleum (Simons et al. (1997), and Ecker et al. (2018)), or sink-holes (Dumm et al. (2018)), the discount in property values, which can be significant, tends to be higher with proximity to the threat and magnitude of the hazard (McClelland et al. (1990)). Zabel and Guignet (2012) find the presence of leaking underground petroleum storage tanks significantly discounts property values by 10% or more. Also, there is evidence that the magnitude of price effects varies depending on information availability and disclosure requirements (Jenkins-Smith et al. (2002)). There is robust evidence for environmental disamenities that are both statistically and economically significant.

There is consensus around the threat posed by septic tank systems and the need to do something about it. While there have been narrow applications of Florida legislation applying to onsite wastewater treatment and disposal systems in limited areas, the state provides funding and grants to support septic tank remediation efforts and, for the most part, leaves the oversight to Municipalities.[10] In Florida, municipalities are empowered to require property owners to update their wastewater treatment disposal system or convert from septic to sewer at the owners' expense.[11]

Initiatives and programs to transition from septic to sewer generally stop at the residents' property line. Miami-Dade County has the Connect 2 Protect program, which aims to expand the system and make it physically feasible for every property currently on septic to connect, but property owners connect at their own expense.[12]

[10] section 373.469, F.S. Applies to BMAP areas (Banana River Lagoon, Central Indian River Lagoon, North Indian River Lagoon) and the Mosquito Lagoon RAP.

[11] See Richardson (2019) for a state-by-state breakdown of mandatory hookup laws.

[12] The Miami Herald Editorial Board, "In Miami-Dade, leaky, smelly septic tanks are on their way out, a victory against sea-level rise," Miami Herald, January 30, 2022.

When an abutting sewer main is identified, the Division of Environmental Resource Management (DERM) notifies the property owner of the access point and gives the owner 90 days under Section 24-43.1(7) of the Miami Dade County Code to connect.[13]

Failing to convert triggers a variety of possible enforcement levers of varying severity. Property owners could be subjected to fines, the ability to pull permits for the property is curtailed, and in extreme cases, a lien could be placed on the property ending in foreclosure.

3 Data and Methodology

Data on transactions and property characteristics is from Miami-Dade County. The raw data file covers 885 thousand unique properties and roughly 3.65 million transactions through May 2022. Information and data on septic systems is aggregated from three sources, Miami-Dade County utility companies, Department of Health (DOH), and Regulation and Economic Resources, Division of Environmental Resource Management (RER/DERM). Since 2021, the utilities operating and servicing water and sewer in Miami-Dade County with the Water and Sewer Department (WASD) have been required to report their water and sewer connections at the property level. Properties that are reported as not connected to sewer are assumed to use an onsite wastewater treatment system and identify probable septic tank systems.[14] The utility's connection data is supplemented with septic tank permits from the Department of Health and information on properties that receive a "Notice of Required Connection (NORC)" from RER/DERM.

The final merged dataset of Miami-Dade County transactions with property-level septic system information excludes observations for missing data fields, outliers by property characteristics[15], restricts to arm's length transactions, and excludes transactions of many folios.

While trimming and restricting raw data to mitigate the impact of outliers or data errors is common, in this case the included sample restrictions aid identification. For example, there is a concern that identifying septic tank system status by "probable" septic system properties includes

[13]Notices of Required Connection (NORC) or Notice of Sewer Availability (NOSA) sent by the Division of Environmental Resource Management (DERM) requires the owner to convert within 90 days as stipulated under Section 24-43.1(7) of the County Code.

[14]Sec. 24-43.11. of the Miami-Dade County Code, "Utilities required to compile and report information related to non-vacant properties that are not served by a public sanitary sewer and not served by public water."

[15]Sample restrictions on property characteristics for number of bedrooms, baths, finished square feet, number of buildings, number of units, effective age, actual age, stories, lot size, and trimmed the top-bottom 1% of transactions by CPI-adjusted prices.

properties that are not connected to a sewer but do not have a septic tank system. Conditioning the analysis on properties with at least one bedroom and bathroom maximizes the probability that probable septic tank systems correctly indicate the presence of onsite wastewater treatment systems. We are confident that the potential for bias from misidentifying properties that are not connected to the sewer as having a septic system is minimal and would bias against finding a result.

Self-selection and septic system eligibility are a concern as well. Onsite wastewater treatment systems are not randomly assigned but are more likely to be present when it is not feasible to connect to the sewer. To address this concern, the sample is restricted to "septic-eligible" properties or similarly situated properties for whom the only difference is septic-sewer status. For example, properties with lot sizes less than 5k are prohibited from installing a septic tank system, so transacted properties are restricted to single-family residences where the lot size exceeds 5k and excludes condominiums.

The final sample of single-family residential transactions includes almost 300 thousand from 2002 to 2022. Nearly 30%, or 88,089, of the transacted properties, are flagged for having a septic tank system. On average, these properties are more expensive, with a higher average CPI-adjusted sales price of 585 thousand compared to 482 thousand for those connected to the sewers. They tend to be older and have larger lots but with fewer bedrooms and baths.

Figure 1 displays the average prices by septic status quarterly. Septic-sewer properties exhibit similar price trends over this period, with septic tank system properties transacting at higher prices, on average. However, there is still a concern that septic-sewer properties differ on unobservables and amenities that correlate with the presence of septic tank systems and not being able to connect.

The following multivariate analysis and model specifications are intended to identify the price effect associated with existing septic tank systems, address identification concerns, and decompose the underlying mechanism of the price effect. Similar to Kiel and Williams (2007), we will exploit factors that might explain variation in the price effect and inform on the underlying mechanism, including the amount of the septic system risk internalized by property owners (well-water status), perception of the risk (extreme weather events), and impacts to the future cash flows or discounted present value of septic systems (NORC-abutting status). Finally, robustness tests to look for variation in the price effect by municipality, cohort, pre-post changes in disclosure requirements, and market segment by price.

4 Analysis

To test for an association between property values and septic system status, we follow established methods for evaluating the impact of amenities and environmental goods by estimating a hedonic regression of house prices at the property transaction level.[16]

$$Y_{izt} = \alpha + \gamma Septic_i + \beta X_i + \alpha_z + \alpha_t + \varepsilon_{izt} \quad (1)$$

The dependent variable, Y_{izt}, is log(Price) for transaction i at time t and ZIP code z. $Septic_i$ is an indicator variable for whether the transacted property (i) is likely to rely on a septic system at the time of sale. The vector of control variables (X_i) accounts for observable property characteristics (i.e., bedrooms, units, stories, buildings, property age, finished square footage, and lot size), while variation due to trends in prices over time and space are accounted for by including sale year-month, α_t, and ZIP code, α_z, fixed effects. In particular, the combination of bucketing properties by lot size and including ZIP code fixed effects controls for geographic variation due to density, neighborhood, and amenities.

Septic Status

For comparison, table 2 displays the coefficient estimates from the base model specification equation 1 with and without covariates, fixed effects, or controls for property characteristics (X_i), sale year-month (α_t), and ZIP code (α_z). The coefficient estimate on the indicator for $Septic_i$ is positive and statistically significant at the 1% level for both. In Column (1) and without controlling for covariates, properties with a septic tank system present are associated with higher transaction prices of 12.9% compared to properties connected to the sewer, on average. In Column (2), the price effect is smaller at 3.2%, but still economically significant. A 3.2% premium for transacted properties on septic systems translates to an average treatment effect on the treated of approximately $13 thousand dollars.

Therefore, we reject the null hypothesis of no price effect in favor of finding a positive and significant association between the presence of a septic tank system and house prices. The result

[16] For a survey of hedonic studies of environmental externalities see Simons and Saginor (2006), and Boyle and Kiel (2001).

is statistically significant at the 1% level, robust to the full set of available controls, and represents an economically significant average treatment effect on the treated.

Septic Status by Municipality

One of the benefits of using septic tank systems to study prices and climate risk is that septic tank systems are a property-level characteristic differentially impacted by sea-level rise. Identifying variation in climate risk and exposure at the property level allows for within-market variation of septic tank status, overcoming the problem of examining climate risks defined by geographic area (e.g., flood zones). Including ZIP code fixed effects controls for differences between markets or ZIP code-level variation in amenities, unobservable characteristics, and prices.

However, from Baldauf et al. (2020), there is evidence that neighborhood-level beliefs about climate risk are important for pricing the risk, and the prevalence of septic tank systems does vary across Miami-Dade County, where some neighborhoods have higher concentrations of septic tank systems than others. To consider variation in the price effect by area, we estimate coefficients of the base model specification by municipality.

The cleaned sample of transactions from Miami-Dade County comprises properties from 34 different municipalities.[17] Selecting municipalities where the number of transactions exceeds 2% of total transactions and at least 1% of the transactions where a septic tank system is present for Miami-Dade County, we look at the City of Miami, Homestead, Cutler Bay, and Palmetto Bay. These four represent a large proportion of total transactions and cover the spectrum of possible septic tank concentrations. On the low end, 2.9% of property transactions for Cutler Bay are flagged for having a septic tank system compared to 82% of transactions in Palmetto Bay.

Table 3 displays positive and significant coefficient estimates for the septic system indicator across municipalities. In Cutler Bay, there is a 2.6% premium associated with septic tank systems, and in Palmetto Bay, the premium is slightly higher at 4.6%. Table 3 provides support that the main result is robust to considering municipalities separately.

[17]See Appendix Table Table A1 for a summary of transactions and septic status by municipality.

Septic and Water Status

Water status, or whether a property is connected to public water or relies on well water, is an important interaction relevant to the cost-benefit considerations and the risks of having a septic tank system. The consumption and cost of water and sewage are directly related and structured similarly. Wells have a high upfront cost, but the operating cost is only the maintenance and upkeep of the well, not proportional to usage, versus water service, which is tied to consumption at rates that can increase over time. Water and sewer are complementary; combining a well with a septic system could be advantageous from an operating cost perspective.

However, there are additional and unique risk considerations in relying on well water that is separate and distinct from an onsite wastewater treatment system. The safety and likelihood of a water service disruption are fundamentally different for properties relying on a well versus those with water service. Property owners are responsible for ensuring well water is potable and appropriately treated. Water quality can vary and requires active monitoring. When the well is operated by a pump, there is additional maintenance and the possibility of disruption due to power outages. Finally, the experience of a disruption in water service is fundamentally different than the experience of a disruption in septic system operations.

Also, water service is important beyond household consumption. Water availability can be critical for fire departments to provide prompt and effective fire response. Properties not supported by public water infrastructure (i.e., fire hydrants) are at an increased risk and threat from fires, which is a consideration for insurers in setting insurance premiums.

As a result, water service is more common than connection to sewer. In the cleaned dataset, 3.2% of transactions are flagged as having a well compared to 30% with a septic system, and they are exclusive to properties with septic tank systems. If a property is connected to a sewer, it is connected to water. The 3.2% of transactions with a well represents 11.7% of the sample of transactions on septic.

A property's reliance on a well for water and septic tank system for wastewater treatment internalizes more of the threat to public health of septic tank systems than properties with a septic tank system and water service. From Arnade (1999) and Murphy et al. (2020), there is a strong correlation between nearby septic systems and poor well water quality, and the impact is exacerbated by rain when septic systems are prone to fail. Therefore, homeowners should be more likely to internalize the public health and environmental risks of their septic tank systems when they also rely on a well for drinking water than similarly situated properties with water service.

To test for differences in the price effect of septic systems related to water status, we estimate the base model specification with indicator variables for septic-well and septic-municipal water properties. The base or comparison group of transactions are the properties connected to sewer and water (non-septic and non-well). Table 4 displays the coefficient estimates for the interaction of septic-sewer and water status. Compared to sewer-water service properties, there is a positive price effect of 3.8% associated with the septic-water service subset of septic tank system properties but a discount of -2.5% for properties with a septic tank system and well, both significant at 1% level.

The result is consistent with an increased perceived risk for parcels on wells with a septic tank system. However, inferences from the analysis of water status are limited because of the small sample and lack of variation of water status amongst the properties connected to the sewer and because there are different cost considerations and risks of water status that are separate and independent of septic status. Finally, the non-random location of wells exacerbates the concern of selection bias. The flag for wells is likely correlated with omitted variables related to the provision of public services and infrastructure.

Septic and NORC-Abutting Status

Miami-Dade County requires properties to abandon septic tank systems and connect to the sewer main when it is physically feasible.[18] In the cleaned sample, there are 4,970 observations where the transacted property is flagged for having a septic tank system and is abutting a sewer main or where a sewer lateral is potentially available. For 451 transactions, the additional step has been taken to notify the property owner by sending them a notice of required connection (NORC), giving them ninety days to connect.[19]

The NORC-Abutting indicator identifies transactions where a septic tank system is present and connecting to the sewer main is physically feasible, which is defined by the presence of an

[18]Sec. 32-78. of the Miami-Dade County Code, "Connection to public water supply and public sewer disposal in abutting streets and easements required; periodic review and reports."

[19]Sec. 32-79. of the Miami-Dade County Code, "Notice to connect; procedure."

abutting sewer main or a requirement to connect has been issued. It does not imply any physical changes to the property or inform on the performance of existing septic tank systems. Instead, the NORC-Abutting indicator captures the risk of being required to connect and corresponding expenses. It overcomes concerns about septic tank systems' non-random location by identifying a change in status, which is external to the property, and primarily impacts the present value or cost-benefit analysis of owning and operating a septic tank system.

Flagging a property as abutting or receiving a NORC is consistent with burdening the owner with the obligation to abandon and remediate an existing septic system regardless of its age and condition and connect to the sewer at the property owner's expense[20]; forego lower operating and maintenance costs of septic tank systems for potentially higher annual wastewater fees and exposure to increases in wastewater rate increases. Failing to comply and connect when required to do so triggers a sliding scale of penalties, from freezing permits to placing a lien on the property.[21]

NORC-abutting status is similar to prior studies that look at changes in insurance or flood zones impacting the user cost independently of the fundamental risk exposure where flood designations and corresponding insurance implications have been found to be informative (Bin et al. (2008)) and capitalized into prices (Shr and Zipp (2019)). Consistent with Georgic and Klaiber (2022) who exploit a change in flood subsidy status at the property level by property age to overcome concerns of spatial correlation between flood zones and amenities and the difficulty of disentangling the disclosure or informativeness of the designation from the user cost implications, NORC-abutting status is a property level designation independent of the risk and characteristics of the built property, including property age. In Miami-Dade County, what it means for a property to abut a sewer main and be within a feasible distance is determined by the county manager.

To test for variation in the price effect for septic systems associated with NORC-abutting status, we estimate the base model specification equation 1 and include the indicator for NORC-abutting status. Table 5 shows price effects for septic-NORC-abutting status. The earlier premium for septic tank system properties increases slightly from 3.2% to 3.8% for septic non-NORC-abutting properties. The marginal effect of NORC-abutting status is associated with a discount of -7% and a cumulative price effect of -3.2% for septic and NORC-abutting.

[20] Expenses include connection fees, abandoning the existing septic tank system, and the expense of physically connecting, which depends on the distance to the sewer main and preexisting sewer lateral.

[21] Sec. 32-80. of the Miami-Dade County Code, "Connection effected by County; lien; recording; redemption."

Prices and the price effect associated with septic tank systems are sensitive to the additional obligations and costs implied by NORC-abutting status. Properties on septic tank systems that find themselves abutting sewer lines or receive a notice of required connection are discounted. The impact is statistically and economically significant, and more work is necessary to determine whether NORC-abutting status triggers housing tenure decisions. In Guignet and Martinez-Cruz (2018), the authors find that leaking underground petroleum storage tanks do explain the homeowner's decision to sell.

Septic Subset Analysis

In the cleaned sample, variation in water and NORC-abutting status is exclusive to the subset of properties where a septic system is present. Properties connected to sewer are also connected to water service. We repeat the water and NORC-abutting analysis conditioned on transactions with septic tank systems to test the robustness of earlier findings within the septic sample. Whereas the prior analysis tested for price effects compared to non-septic or properties connected to sewer, the test here and base group, in this case, are other septic system properties.

Table 6 displays the results for analysis for water and NORC-abutting status when the sample is restricted to transactions of properties with a septic tank system, and the coefficient estimates are consistent with the main results. From Column (1), properties with a septic and a well are associated with a discount of -3.6% compared to septic-water service properties, significant at the 1% level. In Column (2), properties flagged for NORC-abutting are associated with a discount of -6.1% compared to non-NORC-abutting septic properties, again significant at the 1% level. In column (3), both well and NORC-abutting indicators are included, and the signs, economic, and statistical significance of coefficient estimates are unchanged.

Results from the septic system subset analysis support the main findings of variation in the septic system price effect related to water and NORC-abutting status.

Analysis by Cohort and Disclosure Requirements

The sample period covers a volatile period for property markets and changes in available information, awareness, and risk perception of septic tank systems and climate-related risks. From 2017 through 2023, The Miami-Herald has published more than 25 articles about septic tanks, either about pollution or contamination of coastal waters or the grants, programs, and initiatives for mitigation. In addition, since mid-year 2021, sellers have been required by Miami-Dade County to disclose the presence of a septic tank to buyers.[22] While it is unclear how often buyers were unaware of a property's septic tank status, since July 30^{th}, 2021, sellers have been required to disclose the presence of septic tank systems and established liability for failure to disclose. Because the change in disclosure requirements is only material to the segment of properties within the market or those with a septic tank system, we contribute to the disclosure and information revelation literature and test for variation in the price effect before and after the change and between treated (septic) and control (sewer) properties.

Also, using static indicators from 2021 and 2023 to identify properties with septic tank systems and projecting backward through time is likely to misidentify transactions of the septic-to-sewer properties, and the likelihood of misidentifying will be higher at the beginning of the sample period. For example, a transacting property that is connected to the sewer but had a septic system when the property was transacted will be misidentified as being connected to the sewer for that transaction. Fortunately, the error is likely be one way or in identifying properties as being connected to the sewer when they had a septic system at the time of the transaction but connected later, given the unidirectional nature of connecting to the sewer versus disconnecting from the sewer to convert to a septic system, and misidentifying a property as being connected to the sewer when it had a septic system biases against finding a result of a price effect associated with septic tank systems. To address this concern, we include cohort-level analysis.

To test for variation over time in the septic system price effect, we consider four distinct time periods. First, a pre-financial crisis period from 2002 to 2007, followed by the Great Financial Crisis (GFC) from 2008 to 2011. Then, a recovery period spanning 2012 through 2019 and, lastly, the COVID-19 years of 2020 to 2022 bisected by changes in septic system disclosure requirements for transactions in Miami-Dade County.

Table 7 displays coefficient estimates for the base model specification in Panel A, including water status in Panel B and NORC-abutting status in Panel C. The base model coefficient estimates by cohort displayed in Panel A show positive and significant coefficient estimates and imply the

[22] Sec. 21-49.1 of the Miami-Dade County Code requires, "disclosures regarding septic tank systems for real estate transactions."

premium for septic tank systems holds across periods. While it is difficult to compare the pre-post disclosure periods because of the unique impact of COVID-19, the properties transacted from August 2021 are associated with a larger price effect (4.1%) than those transacted in 2020 or the first half of 2021 (1%). The coefficient estimates across the cohorts are all positive and significant at the 1% level, with the largest price effect of 4.1% in column (6) from the last cohort.

In Table 7 Panel B, the premium for the septic-water service subset of transactions is consistently positive and significant across the cohorts and of similar magnitudes, and the largest price effect of 5.3% is reported in column (6), the post-disclosure cohort. The coefficient estimate for septic-well is not significant until the 2012 to 2022 cohorts. Findings are consistent with a time-varying discount associated with the combination of septic and well that evolved over the sample period.

Figure 2 informs on the time trend by displaying the coefficient estimates and standard errors from estimating the base model, water status, and NORC-abutting status specifications separately by year. In Panel B, we do see a shift in the price effect specific to the subset of septic-well properties in 2012. At this point, the trends for septic with and without water connection deviate, and there exists a persistent discount for the septic-well population of properties.

Table 7 Panel C displays the NORC-abutting price effect results that are consistent with the earlier finding of a significant discount present for NORC-abutting septic properties across cohorts. The coefficient estimates for the 2002 to 2007 cohort are remarkably similar to those of the last cohort in column (6), or 4.6% to 4.7% premium for septic tank systems and -8.6% and -6.7% discount associated with NORC-abutting status, respectively.

Whereas Beck and Lin (2020) finds the discount related to the risk of sea-level rise increasing over time, from the analysis of septic tank systems, there is an economically and statistically significant premium for septic tank systems that persists across periods. However, there is variation over time with respect to water and NORC-abutting statuses. While time is a poor proxy alone for information revelation and awareness, we are not able to confirm findings from prior studies on the importance of information to internalizing the risk (Hino and Burke (2021), Gayer and Kip Viscusi (2002), and Gayer et al. (2000)). For example, the strong premium and price effect post-disclosure requirement and conclusion from prior studies on property disclosures that find the impact of such disclosures depends on the availability of the information before the disclosure suggests the septic tank system disclosure is not revealing new information to buyers for internalizing the risk (Pope

(2008) and Walsh and Mui (2017)).

Analysis Pre-Post Weather Events

Extreme weather events identify a point in time when, for example, the flood, hurricane, or climate-related risk is brought to the forefront, and the threat is salient to market participants. Given that the concern with septic systems is that they fail when the groundwater level is too high, major weather events are also periods when septic tanks are prone to fail.

Prior studies find higher price differentials in the immediate post-period that diminish over time. The discount in prices tends to be correlated with the perceived threat (Bakkensen and Barrage (2022)), so the proximity of the property to the impacted areas or flood zones (Bin and Landry (2013) and Cohen et al. (2021)) and the severity of the event (Kim and Hammitt (2022)). For example, Graham et al. (2007) finds a temporal shift in prices from hurricanes that recover over time, and Fang et al. (2023) finds that the severity of the hurricane season or distant hurricanes alone is sufficient to temporarily impact buyers' perception of hurricane-related risk.

Similar to Kim and Hammitt (2022), we look at the period following storms as representing a period of heightened sensitivity or salience to the risks. The prior model is extended to test for changes in the price effect for the 3 and 6 months after major weather events. Specifically, we look at the tropical storms and hurricanes that hit South Florida over the sample period and compare the prices between septic and non-septic property transactions. From 2002 through 2022, there were two tropical storms (Nicole, September 29, 2010, and Andrea, June 6, 2013) and two hurricanes (Irma, September 10, 2017, and Matthew, October 7, 2016). The storms all occur at similar times of the year, including sale-year-month fixed effects controls for seasonality and the properties connected to sewer controls for general trends in the housing markets in the post-period.

Table 8 columns (1) and (3) show coefficient estimates from the base model specification with an indicator for the post-period of major weather events and the interaction of septic systems with the post-period. For both 3 and 6-month post-period perspectives, the main septic system premium is positive and significant at the 1% level. The coefficient estimates for interaction terms of the septic system indicator with 3 and 6-month post periods are both -1.8% and statistically significant at the 1% level.

Within the subset of properties on septic tank systems, those with a well should be more sensitive than septic properties with water service to the impact of major weather events. Table 8 columns (2) and (4) include coefficient estimates for water status and the interaction of water status and post-period indicator. Summing across the post-period septic and septic-well coefficient estimates implies a discount for the post-period of -5% and -6% at 3 and 6 months, respectively.

The results are consistent with major weather events elevating the perceived risk and threat of septic systems compared to similarly situated properties connected to sewer leading to a short-term discount in prices. Also, the combination of septic-well sees higher discounts capturing the marginal health risk septic-well properties internalize around flooding events.

Analysis Above/Below Median Property Value

To test whether the results are robust across the market segmented by price, the model specifications for septic system, water, and NORC-abutting status are estimated separately by transactions above/below median sales price by year.

Table 9 compares the main result and the results for the top and bottom half of transactions by sales price. From Panel A, the premium associated with septic systems holds across price segments. The coefficient estimates are positive and significant at the 1% level, with the subset of transactions below the median exhibiting a slightly smaller price effect of 1.1% compared to those above the median sales price at 2.6%.

Table 9 Panel B reports results considering water status and price. The main result of a premium for septic-water service and discount for septic-well holds for the top half of transactions by price. For the bottom half, there is still a positive and significant price effect associated with septic-water service, but the discount for septic-well has gone away. There is not a significant association between price and septic-well for the bottom half of transactions by price, implying that the price effect for septic-water status varies with price, and less expensive properties are less sensitive to the presence of a well.

In Table 9 Panel C, the indicator for NORC-Abutting status is considered by price segment where the results imply lower-priced properties are more sensitive to the impact of NORC-abutting status than higher-priced properties. The discount of -8.1% for the bottom half is significant at the 1% level, while the price effect is not significant for the top half of transactions by price. The findings are consistent with costs or the connection charge, construction, and abandonment being mostly fixed expenses that have a disproportionate impact on less expensive properties.

The evidence from segmenting the market by price demonstrates that the price premium associated with septic systems holds across property values. However, there is variation in the sensitivity or price effects related to water and NORC-abutting status by price.

5 Conclusion

This study facilitates the conversation on septic tanks and highlights a unique setting for studying climate-related risks. Septic tank systems identify a property-level characteristic that increases properties' sensitivity to climate risk due to sea-level rise. The concern is primarily public, while owners benefit privately. It is a unique setting where climate risk and exposure vary at the property level, and private interests do not align with the public's.

A septic tank system can be expensive, but once installed, the operating and maintenance costs are low. A properly maintained system can last decades, cost less than sewer wastewater fees, and insulate property owners from wastewater rate increases. However, properties that rely on septic tank systems require a buffer of dry ground, and sea-level rise compromises low-lying septic tank systems in coastal areas, threatening public health and the environment.

After controlling for observable property characteristics, geography, and time, we find that properties with septic tank systems transact at higher prices than similarly situated properties connected to the sewer. The investment and lower user cost associated with septic systems are capitalized in property values. The result is statistically significant, economically significant, and robust. Market participants are most likely to internalize the risk when the property also relies on a well, such that a compromised septic tank system directly impacts the property's drinking water; following major weather events when the risk is most salient; or when the requirement to connect to the sewer at the owner's expense is imminent. Finally, requiring sellers to disclose the presence of a septic tank system is not associated with a change in the historical premium.

Septic tanks in low-lying areas threaten public health and the environment. There is consensus and support for mitigating and remediating the risk they pose. However, when the property owner bears the cost of converting to sewer, fees for sewer are higher than maintaining a septic system, and there's a significant upfront cost in installing a septic tank, the incentive to mitigate the public threat they pose conflicts with the benefit of a working and operational septic system for the property owner.

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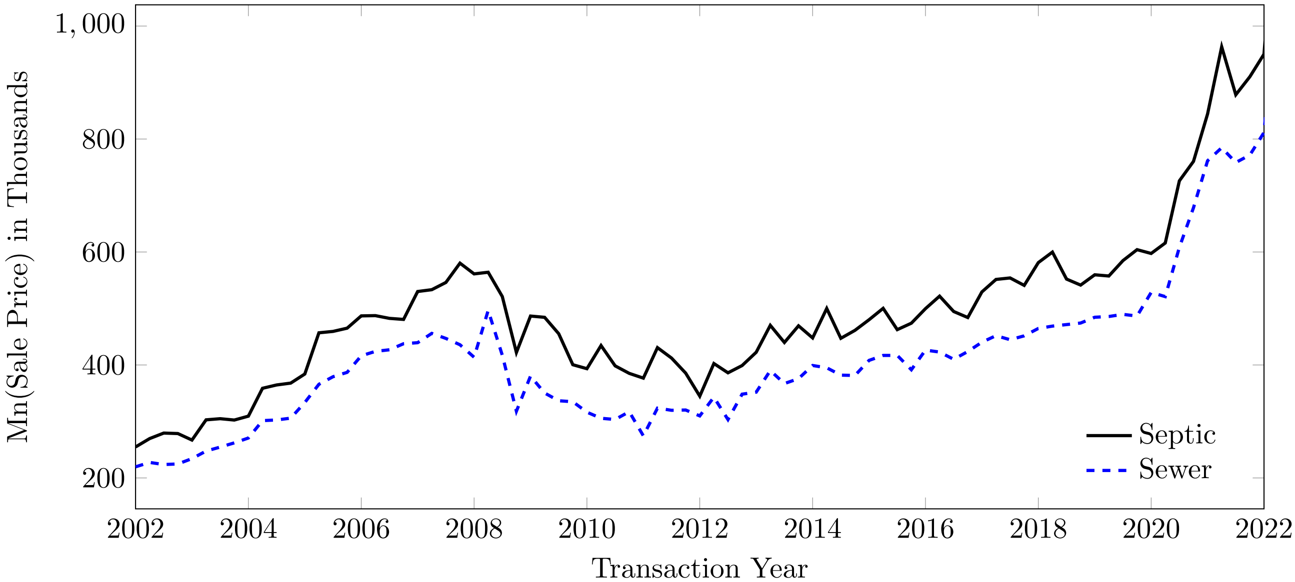
Figures

Figure 1. Quarterly Average Prices for Transacted Properties in Miami-Dade County between 2002 and 2022 by Septic/Sewer.



Note: Figure shows the average sales price for Miami-Dade County transactions with a septic system versus those connected to the sewer utility from 2002 through May 2022.

Tables

Table 1. Mean Differences. Residential properties that were transacted between 2002 and 2022 for Miami-Dade County by properties with/without a septic tank.

	All		Sewer		Septic		Septic-Sewer Difference		
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Difference	t-stat	p-value
Price	373,713	288,193	349,598	258,370	430,048	341,471	80,449	-69.90	0.00
CPI Adj Price	512,979	371,188	481,976	331,970	585,405	441,263	103,428	-69.77	0.00
Ln(Sale Price)	12.61	0.64	12.58	0.60	12.71	0.74	0.13	-50.02	0.00
Ln(CPI Adj Price)	12.95	0.61	12.92	0.57	13.04	0.70	0.12	-47.88	0.00
Septic System	29.98	45.81	0.00	0.00	100.00	0.00	100.00	.	.
Sewer	70.03	45.81	100.00	0.00	0.00	0.00	-100.00	.	.
Septic 2021 not 2023	0.15	3.90	0.02	1.53	0.45	6.72	0.43	-27.41	0.00
Well Water	3.18	17.55	0.00	0.00	10.61	30.80	10.61	-156.33	0.00
NORC-Abutting-Lateral	1.73	13.05	0.00	0.00	5.78	23.35	5.78	-112.41	0.00
Age	39.04	24.49	35.02	25.19	48.44	19.79	13.43	-140.67	0.00
Effective Age	28.03	21.44	26.04	21.60	32.69	20.32	6.65	-77.86	0.00
Living SqFt	1,971	803.28	1,950	721.38	2,020	966.22	69.28	-21.44	0.00
Actual SqFt	2,415	1,032	2,369	895.70	2,524	1,290	155.36	-37.46	0.00
Lot SqFt	10,494	16,882	7,923	3,400	16,498	29,534	8,574	-129.70	0.00
Bedrooms	3.41	0.95	3.46	0.94	3.28	0.96	-0.18	47.74	0.00
Baths	2.16	0.88	2.18	0.85	2.09	0.93	-0.09	26.55	0.00
Number of Stories	1.16	0.38	1.20	0.42	1.08	0.27	-0.13	82.74	0.00
Units	1.10	0.39	1.10	0.41	1.09	0.34	-0.01	5.56	0.00
Number of Buildings	1.12	0.35	1.11	0.33	1.15	0.39	0.04	-31.46	0.00
Observations	293,871		205,782		88,089				

Note: Table 1 displays means, standard deviations, and mean differences for transactions with a septic system versus those connected to the sewer utility for Miami-Dade County from 2002 through May of 2022.

Table 2. Ln(Price) for Miami-Dade Transactions from 2002 through 2022.

Dependent Variable: Ln(Price)	(1)	(2)
Septic System	0.129***	0.032***
	(0.003)	(0.002)
Bedrooms==2		0.065***
		(0.012)
Bedrooms==3		0.086***
		(0.012)
Bedrooms==4		0.091***
		(0.012)
Bedrooms>4		0.075***
		(0.012)
Units≥2 & Units≤4		-0.120***
		(0.003)
Stories==0		-0.184***
		(0.014)
Stories==2		0.018***
		(0.002)
Stories>2		0.221***
		(0.028)
Buildings>1		-0.035***
		(0.002)
Age		-0.008***
		(0.000)
Effective Age		-0.001***
		(0.000)
Age Squared		0.000***
		(0.000)
Effective Age Squared		-0.000***
		(0.000)
Living SqFt		0.000***
		(0.000)
Ln(Living SqFt)		0.384***
		(0.011)
Lot SqFt		-0.000***
		(0.000)
Lot SqFt Squared		0.000***
		(0.000)
Ln(Lot SqFt)		0.319***
		(0.004)
Lot SF > 5 & ≤ 10k		-0.025***
		(0.003)
Lot SF > 10 & ≤ 20k		-0.004
		(0.004)
Lot SF > 20k		-0.048***
		(0.006)
Constant	12.576***	6.345***
	(0.001)	(0.083)
Adjusted R-squared	0.01	0.83
Observations	293,871	293,871
Sale-Year-Month FE		Y
Zip Code FE		Y

Note: Table 2 displays coefficient estimates for transactions for Miami-Dade County from 2002 through May of 2022. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 3. Ln(Price) for Miami-Dade Transactions by Municipality.

Dependent Variable: Ln(Price)	All (1)	City of Miami (2)	Homestead (3)	Cutler Bay (4)	Palmetto Bay (5)
Septic System	0.032***	0.260***	0.068***	0.026**	0.047***
	(0.002)	(0.011)	(0.010)	(0.012)	(0.009)
Constant	6.345***	9.817***	6.146***	8.011***	6.334***
	(0.083)	(0.883)	(0.400)	(0.373)	(0.748)
Adjusted R-squared	0.83	0.79	0.82	0.87	0.83
Observations	293,871	32,108	11,089	10,399	6,660
Property Characteristics	Y	Y	Y	Y	Y
Sale-Year-Month FE	Y	Y	Y	Y	Y
Zip Code FE	Y	Y	Y	Y	Y

Note: Table 3 displays coefficient estimates for the top/bottom half of transactions by sales price by transaction year cohort for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively. See Appendix Table Table A1 for a summary of transactions and septic status by municipality.

Table 4. Ln(Price) for Miami-Dade Transactions by Septic and Water Status.

Dependent Variable: Ln(Price)	(1)	(2)
Septic System	0.032***	
	(0.002)	
Septic with Well Water		-0.025***
		(0.004)
Septic with Water Service		0.038***
		(0.002)
Constant	6.345***	6.316***
	(0.083)	(0.082)
Adjusted R-squared	0.83	0.83
Observations	293,871	293,871
Property Characteristics	Y	Y
Sale-Year-Month FE	Y	Y
Zip Code FE	Y	Y

Note: Table 4 displays coefficient estimates for the top/bottom half of transactions by sales price by transaction year cohort for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 5. Ln(Price) for Miami-Dade Transactions by Septic and NORC-Abutting Status.

Dependent Variable: Ln(Price)	(1)	(2)
Septic System	0.032***	0.038***
	(0.002)	(0.002)
NORC-Abutting-Lateral		-0.070***
		(0.005)
Constant	6.345***	6.377***
	(0.083)	(0.083)
Adjusted R-squared	0.83	0.83
Observations	293,871	293,871
Property Characteristics	Y	Y
Sale-Year-Month FE	Y	Y
Zip Code FE	Y	Y

Note: Table 5 displays coefficient estimates for the top/bottom half of transactions by sales price by transaction year cohort for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 6. Ln(Price) Restricted to Subset of Septic Tank Properties from Miami-Dade Transactions.

Dependent Variable: Ln(Price)	Within Septic Systems (1)	(2)	(3)
Well Water	-0.036***		-0.031***
	(0.004)		(0.004)
NORC-Abutting-Lateral		-0.061***	-0.058***
		(0.005)	(0.005)
Constant	5.935***	6.014***	6.001***
	(0.120)	(0.122)	(0.121)
Adjusted R-squared	0.85	0.85	0.85
Observations	88,089	88,089	88,089
Property Characteristics	Y	Y	Y
Sale-Year-Month FE	Y	Y	Y
Zip Code FE	Y	Y	Y

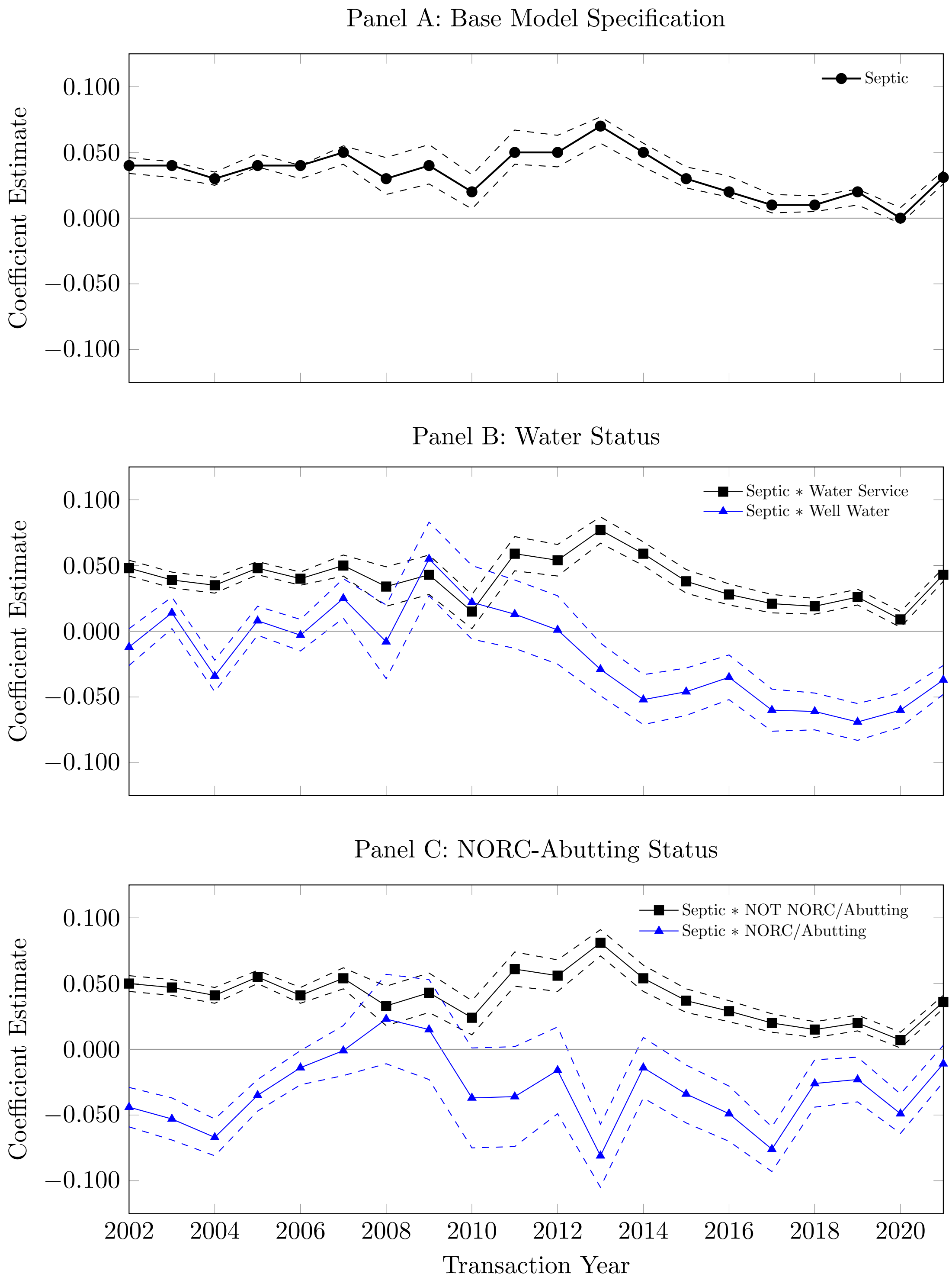
Note: Table 6 displays coefficient estimates when the sample of transactions is restricted to only those identified as having a septic system for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 7. Ln(Price) for Miami-Dade Transactions by Cohort.

Dependent Variable: Ln(Price)	All (1)	2002 - 2007 (2)	2008 - 2011 (3)	2012 - 2019 (4)	2020 - JUL-21 (5)	AUG-21 - MAY-22 (6)
A. Base Model Specification						
Septic System	0.032***	0.037***	0.036***	0.026***	0.010**	0.041***
	(0.002)	(0.002)	(0.007)	(0.003)	(0.004)	(0.008)
Constant	6.345***	6.859***	6.525***	5.634***	6.823***	7.407***
	(0.083)	(0.130)	(0.217)	(0.129)	(0.159)	(0.342)
Adjusted R-squared	0.83	0.83	0.80	0.82	0.85	0.78
Observations	293,871	130,291	26,266	102,777	23,395	11,142
B. Water Status						
Septic with Well Water	-0.025***	-0.006	0.005	-0.055***	-0.044***	-0.046***
	(0.004)	(0.005)	(0.014)	(0.006)	(0.009)	(0.017)
Septic with Water Service	0.038***	0.041***	0.038***	0.035***	0.017***	0.053***
	(0.002)	(0.002)	(0.007)	(0.003)	(0.005)	(0.008)
Constant	6.316***	6.833***	6.510***	5.608***	6.800***	7.434***
	(0.082)	(0.129)	(0.217)	(0.128)	(0.159)	(0.347)
Adjusted R-squared	0.83	0.83	0.80	0.82	0.85	0.78
Observations	293,871	130,291	26,266	102,777	23,395	11,142
C. NORC-Abutting Status						
Septic System	0.038***	0.046***	0.040***	0.033***	0.014***	0.047***
	(0.002)	(0.002)	(0.007)	(0.003)	(0.005)	(0.008)
NORC-Abutting-Lateral	-0.070***	-0.086***	-0.050**	-0.072***	-0.047***	-0.067***
	(0.005)	(0.006)	(0.019)	(0.008)	(0.012)	(0.021)
Constant	6.377***	6.900***	6.539***	5.664***	6.845***	7.439***
	(0.083)	(0.131)	(0.217)	(0.130)	(0.159)	(0.341)
Adjusted R-squared	0.83	0.83	0.80	0.82	0.85	0.78
Observations	293,871	130,291	26,266	102,777	23,395	11,142
Property Characteristics	Y	Y	Y	Y	Y	Y
Sale-Year-Month FE	Y	Y	Y	Y	Y	Y
Zip Code FE	Y	Y	Y	Y	Y	Y

Note: Table 7 displays coefficient estimates for the top/bottom half of transactions by sales price by transaction year cohort for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Figure 2. Coefficient Estimates on Septic, Water, and NORC-Abutting Status by Year.



Note: Figure shows the coefficient estimates on indicators for Septic System, Water Status, and NORC-Abutting Status by year from 2002 through May 2022 for Miami-Dade County transactions. For Panels A, B, and C, the 2022 transactions (January through May) are included with 2021 transactions for estimation. The model specification is consistent with the main base specification of Sale-Year-Month FE, Zip Code FE, and controls for Property Characteristics. The dashed lines represent one standard error.

Table 8. Ln(Price) in the 3 and 6-months after Hurricanes (Matthew and Irma) and Tropical Storms (Nicole and Andrea).

	Post-Period of			
Dependent Variable:	3-Months		6-Months	
Ln(Price)	(1)	(2)	(3)	(4)
Post-Weather Event	0.002	0.001	-0.002	-0.002
	(0.009)	(0.009)	(0.008)	(0.008)
Septic System	0.032***	0.037***	0.033***	0.038***
	(0.002)	(0.002)	(0.002)	(0.002)
Septic*Post-Weather Event	-0.018***	-0.015**	-0.018***	-0.013***
	(0.006)	(0.007)	(0.005)	(0.005)
Septic with Well		-0.060***		-0.058***
		(0.004)		(0.004)
Septic-Well*Post-Weather Event		-0.035*		-0.047***
		(0.018)		(0.013)
Constant	6.345***	6.313***	6.346***	6.315***
	(0.082)	(0.082)	(0.082)	(0.082)
Adjusted R-squared	0.83	0.83	0.83	0.83
Observations	293,871	293,871	293,871	293,871
Property Characteristics	Y	Y	Y	Y
Sale-Year-Month FE	Y	Y	Y	Y
Zip Code FE	Y	Y	Y	Y

Note: Table 8 displays coefficient estimates for the 3 and 6-months after Hurricanes (Matthew and Irma) and Tropical Storms (Nicole and Andrea) for Miami-Dade County. The post-period is defined in event time to include Hurricane Irma on September 10th, 2017; Hurricane Matthew on October 7th, 2016; Tropical Storm Nicole on September 29th, 2010; and Tropical Storm Andrea on June 6th, 2013. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 9. Ln(Price) for Miami-Dade Transactions by Sales Price Percentiles.

Dependent Variable: Ln(Price)	All (1)	By Median Price < (2)	By Median Price ≥ (3)
A. Base Model Specification			
Septic System	0.032***	0.011***	0.026***
	(0.002)	(0.002)	(0.002)
Constant	6.345***	6.400***	8.510***
	(0.083)	(0.097)	(0.189)
Adjusted R-squared	0.83	0.75	0.83
Observations	293,871	146,372	147,499
B. Water Status			
Septic with Well Water	-0.025***	0.008	-0.026***
	(0.004)	(0.005)	(0.004)
Septic with Water Service	0.038***	0.013***	0.030***
	(0.002)	(0.002)	(0.002)
Constant	6.316***	6.404***	8.473***
	(0.082)	(0.097)	(0.189)
Adjusted R-squared	0.83	0.75	0.83
Observations	293,871	146,372	147,499
C. NORC-Abutting Status			
Septic System	0.038***	0.021***	0.026***
	(0.002)	(0.002)	(0.002)
NORC-Abutting-Lateral	-0.070***	-0.081***	-0.008
	(0.005)	(0.005)	(0.005)
Constant	6.377***	6.444***	8.512***
	(0.083)	(0.097)	(0.189)
Adjusted R-squared	0.83	0.75	0.83
Observations	293,871	146,372	147,499
Property Characteristics	Y	Y	Y
Sale-Year-Month FE	Y	Y	Y
Zip Code FE	Y	Y	Y

Note: Table 9 displays coefficient estimates for the top/bottom half of transactions by sales price by transaction year cohort for Miami-Dade County from 2002 through May of 2022. Controls include Sale-Year-Month FE, 5-digit Zip Code FE, and Property Characteristics, such as number of bedrooms, number of units, number of stories, number of buildings, property age (actual and effective), square feet of living space, and lot size. The figures in parentheses are White standard errors of the coefficient estimates. 1, 2, and 3 stars indicate statistical significance at 10%, 5%, and 1%, respectively.

Additional Tables and Figures

Table A1. Summary of Transactions by Municipality

Municipality	Transactions	Septic Tank	Septic & Well	NORC-Abutting
Aventura	202	14	0	1
Bal Harbour	39	0	0	0
Bay Harbor Islands	191	18	18	18
Biscayne Park	1,147	1,090	2	44
Coral Gables	9,456	6,849	16	82
Cutler Bay	10,399	306	28	77
Doral	3,978	165	24	21
El Portal	830	829	2	0
Florida City	1,072	18	12	7
Golden Beach	97	2	0	2
Hialeah	11,921	6	6	0
Hialeah Gardens	190	127	3	26
Homestead	11,089	1,245	55	319
Key Biscayne	516	48	1	48
Medley	11	0	0	0
Miami	32,108	1,693	147	224
Miami Beach	4,484	0	0	0
Miami Gardens	16,087	4,863	134	108
Miami Lakes	4,177	15	13	14
Miami Shores	3,836	3,814	2	3
Miami Springs	2,491	1	1	1
North Bay Village	399	0	0	0
North Miami	7,227	8	1	7
North Miami Beach	5,800	5,461	126	138
Opa-locka	1,681	2	1	0
Palmetto Bay	6,660	5,446	147	219
Pinecrest	3,684	3,596	456	99
South Miami	2,220	1,756	35	85
Sunny Isles Beach	394	33	0	33
Surfside	1,209	29	26	29
Sweetwater	566	421	2	85
Unincorporated County	148,470	49,916	7,779	3,361
Virginia Gardens	292	282	282	10
West Miami	948	36	32	35
Total	293,871	88,089	9,351	5,096

Note: Table A1 displays the number of transactions for Miami-Dade County from 2002 through May of 2022 by the municipality.

Figure A1. Plan of Action Report: A Risk-Based Approach to Septic Systems Vulnerable to Sea Level Rise, *Miami-Dade County WASD-RER* (December 2020).