# Toxic Pollution Hazard and Cost of Mortgage Credit

**by**

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**Abstract:** This research explores the impact of carcinogen exposure on mortgage credit costs in the U.S. housing market by utilising the Home Mortgage Disclosure Act (HMDA) and the Toxic Release Inventory (TRI) dataset. In the baseline result, the analysis identifies a modest premium in mortgage rate spreads for properties exposed to carcinogens, which is consistent with the impact of other long-term risks.

The study also examines how carcinogen exposure affects mortgage interest rates across different racial groups, lender types (bank vs. non-banks), and loan purposes (refinancing vs. new purchase). The findings reveal varying impacts among racial groups, with Black and African American applicants experiencing a higher mortgage credit premium due to carcinogen exposure, exacerbating environmental disparities in the financial sector. The study also finds that lender types and loan purposes do not significantly alter the relationship between carcinogen exposure and mortgage credit costs.

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## Introduction

Over the past decade, cancer incidence has surged by 33%, driven primarily by factors such as population ageing, accounting for 16% of this increase, population growth contributing 13%, and changes in age-specific rates contributing 4%. (Fitzmaurice et al., 2018). It is estimated that every year, there are 17.5 million cases of cancer globally, resulting in 8.7 million deaths.

In addition to the health burden, cancer also imposes a substantial weight on the economic conditions of both individuals and the society. The burden of cancer also lead to substantial economic burden. The United States, in particular, bears a considerable financial load in terms of expenses related to cancer-related medical care.They amounted to $183 billion in 2015 and are projected to surge by 34% to reach $246 billion by 2030 (Mariotto et al., 2020). On an individual scale, these expenses fluctuate between $5,300 and $105,000 annually, varying according to the different phases of cancer. Beyond the direct medical costs, people suffering from cancer and their families must endure the intangible costs in terms of years of work lost. In their estimation, Yabroff et al., (2008) found that the cost of cancer mortality is notably higher when accounting for the loss of household duties and caregiving, in addition to the standard wage-earning jobs.

The economic risks linked to cancer, therefore, should be well-considered by financial market participants, especially the housing sector. Prospective homebuyers should anticipate lower property valuations in regions with heightened carcinogen exposure. On the other hand, lenders may opt to apply elevated interest rates to individuals deemed to possess greater health risks. Cancer-related health conditions that could potentially lead to increased medical expenses or reduced income-generating capacity might cause lenders to view the borrower as riskier. To offset this perceived risk, lenders might implement an increase in the loan's interest rate.

This research investigates the effect of carcinogen exposure on the cost of mortgage credit in the U.S. market. I exploit the spatial variation in the amount of carcinogen release and mortgage rate spread across U.S. counties to answer the question: Does the exposure to carcinogen chemicals increase mortgage costs in the U.S? Using a sample of 977,922 conventional 30-year mortgages distributed across 1,829 counties within the United States from 2018 to 2012 combined with the carcinogen release data from the Toxic Release Inventory (TRI) datasets, I find a premium in mortgage rate spread associated with properties exposed to carcinogenic chemicals. The premium is modest and consistent with the impacts of other types of long-term risk on mortgage rate spread (Nguyen et al., 2022).

I further examine the heterogenous impact of carcinogen exposure on mortgage interest rates across different racial groups, types of lenders and types of loan purposes. The results show that the impact of carcinogen exposure on rate spread varies by the applicant's racial group. Specifically, the Black and African American groups experience a higher mortgage credit premium associated with carcinogen exposure compared to other ethnicities, adding to the environmental inequality in the financial market (Ahlers, 2016; Banzhaf et al., 2019; Josey et al., 2023; Laub, 1999). However, the results indicate that types of lenders (bank vs. non-banks) and types of loan purposes (refinancing vs. new-purchase) do not have a changing

effect on the relationship between carcinogen exposure and the cost of mortgage credit.

The composition of this research is as follows: the first part provides the background on environmental inequality in the housing market and the Toxic Release Inventory, the second part summarises the data and variables used in this analysis, the third part describes the empirical model, the fourth and fifth part provide the results of the main and additional analyses.

# 1. Background and Hypothesis

### 1.1.    Environmental hazards and mortgage market

The housing market's vulnerability to environmental hazards has received substantial attention in recent years. With increasing awareness of the potential health and safety risks associated with pollution, toxic emissions, and other environmental hazards, prospective homebuyers and current homeowners are increasingly factoring these considerations into their housing decisions. These concerns extend beyond aesthetics and location; they encompass issues like air and water quality, proximity to industrial facilities, and the overall sustainability of a neighbourhood.

Research has found empirical findings about the impacts of environmental hazards on housing prices. Yusuf & Resosudarmo (2009) find that air pollutants such as lead, total hydrocarbon (THC), and SO2 have a negative association with property value, with housing rental prices being negatively affected by these pollutants, by using a hedonic property value analysis with combined data on housing rental prices and their characteristics. Mastromonaco (2015) explores how the U.S. Environmental Protection Agency's Toxic Release Inventory (TRI) program impacts housing prices, by exploiting the changes in TRI reporting rules for lead in 2001 as a natural experiment and finds that listing a firm in the TRI can reduce housing prices by up to 11% within about a mile, indicating that housing markets react to information from the TRI program. Bui & Mayer (2003) examine the effectiveness of the Toxics Release Inventory (TRI), a regulation requiring firms to disclose toxic emissions information. The findings suggest that public activism and information disclosure through TRI have a limited impact on toxic release reduction and house prices, raising doubts about the efficiency of disclosure rules as a sole form of environmental regulation.

Among different kinds of pollution, a significant strand of literature has focused on carcinogenic pollution. EPA defined carcinogenic or cancer risks (CR) as "the incremental probability of an individual to develop cancer, over a lifetime, as a result of exposure to a potential carcinogen". Kohlhase (1991) finds that when a toxic waste site is added to the list of Superfunds – a , a new market for "safe" housing is created, resulting in a premium for homes located farther from the waste site. This premium disappears after the site has been cleaned. In the reverse view, studies have shown that the cleanup of hazardous waste sites leads to an appreciation in house prices, particularly at the lower percentiles of the housing value distribution (Gamper-Rabindran & Timmins, 2013; Thayer et al., 1992).

However, in the context of the housing market, measuring the price of properties only provides the perspective of the borrowers. It is possible that mortgage lenders

might not internalise risk information and react to risks in the same manner as borrowers. Lenders usually have an informational advantage and also have the capability to utilise information, while borrowers' risk perceptions and beliefs might be led by other factors rather than scientific facts. For example, regarding environmental issues, it has been found that there is a difference between scientifically assessed risk and individuals' perceived risk, with the public often having different beliefs about environmental risk compared to experts. (Lindell & Earle, 1983; Sjoberg, 1999).

In certain situations where environmental emergencies or contaminations happen, lenders might need to deal with not only the negative impact on their loans and collaterals, but also the unfavorable environmental legal framework. For example, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) does not specify the time period when a foreclosing lender can sell the property to be exempted from direct environmental liabilities. This introduces uncertainties for lenders if they want to secure both the liability exemption and the optimal timing to sell the properties. (Xu & Xu, 2020).

These conditions create a motivation for lenders to impose premium when pricing an asset exposed to environmental risks, which has been identified by empirical research. Costaras (1996) shows that portfolios formed according to companies' levels of toxic emissions exhibit noteworthy average returns, implying the existence of a pollution premium not attributable to existing systematic risks or other variables. Painter (2020) find that counties vulnerable to climate change impacts pay higher underwriting fees and initial yields when issuing long-term municipal bonds compared to less vulnerable counties. Nguyen et al., (2022) find that lenders tend to charge higher mortgages' interest rates for properties that have a higher risk of sea level rise, although this interest premium is modest and varies among lenders.

### 1.2.    Toxic Release Inventory and Environmental Inequality

The Toxic Release Inventory (TRI) constitutes a fundamental component of environmental oversight in the United States, overseen and administered by the U.S. Environmental Protection Agency (EPA). This database serves as a comprehensive, publicly accessible repository that provides information on the release, management, and disposal of toxic chemicals by industrial facilities. The Toxic Release Inventory is a result of the Emergency Planning and Community Right-to-Know Act (EPCRA), a legislation passed by the U.S. Congress in response to the raising public awareness about toxic chemicals in industrial activities after the Union Carbide disaster in Bhopal, India. The Union Carbide incident, regarded as the worst industrial disaster in history, led to thousands of immediate deaths and subsequent fatalities due to toxic chemicals exposure, prompting heightened public concern about chemical storage, releases, and emergency response.

Even though organizations provide this data voluntarily to the EPA, the agency has the authority to impose fines for non-compliance based on EPCRA and can compel corrective actions. Information about releases from TRI facilities and their locations has been accessible annually from 1987 to the present. Since its establishment, there has been a notable decline in toxic emissions within the United States since the TRI's inception. For instance, between 1989 and 1999, emissions decreased

by 40% (Bui & Mayer, 2003). Nevertheless, not all facilities submit reports every year. This discrepancy may stem from factors like halting production, reducing toxic chemical usage to levels below reporting thresholds or altering production processes or outputs to exclude these hazardous substances. Furthermore, doubts have arisen regarding the precision of emissions data in the TRI. For example, Marchi & Hamilton (2006) assert that the decreases in reported emissions within the TRI do not align with data collected by ambient pollution monitors under the EPA. Due to these inefficiencies, it remains uncertain whether the public effectively incorporates information from the TRI into their decision-making processes, as evidenced by mixed results in housing and stock markets. However, in recent years, EPA has made considerable efforts to improve the credibility and impact of the Toxic Release Inventory. For example, The EPA annually releases the TRI National Analysis, which analyses reported TRI data to assess trends in pollution prevention activities, including detailed examinations of specific industry sectors, noteworthy chemicals, and geographical data visualisation tools. This encourages both researchers and public and private sectors to engage in using the TRI.

## 1.3.    Hypothesis Development

Based on the empirical findings on the topic, I propose the following hypothesis. Considering a mortgage market with two main actors: the mortgage Lender, and the mortgage Borrower. Suppose the mortgage Borrower wants to acquire a property exposed to carcinogenic waste, which has complete disclosure information on the Toxic Release Inventory dataset. The Borrower goes to the mortgage Lender to apply for a loan.

From the standpoint of the Borrower, the potential health hazards associated with the property prompt certain expectations on the mortgage's cost of credit. Specifically, the Borrower might predict a possible reduction in the property's market price compared to the housing market; therefore, expect a corresponding discount in the applicable mortgage interest rate. Research using the Toxic Release Inventory dataset has found empirical findings indicating a noticeable decline in property values due to exposure to toxic waste (Gamper-Rabindran & Timmins, 2013; Kohlhase, 1991; Thayer et al., 1992).

On the other side, the mortgage Lender holds a contrary expectation. The Lender interprets that the property's exposure to carcinogens might make the potential tenants (the Borrower) more vulnerable to cancer, which in turn can lead to impending financial problems. Mariotto et al. (2020) and Yabroff et al. (2008) show a significant linkage between carcinogenic issues and financial hardship, due to the considerable medical expenses often associated with cancer and the potential reduction in the individual's capacity to work. As a response, the mortgage Lender might consider the introduction of a premium on the mortgage interest rate. This marginal cost is akin to a form of risk insurance, as it would compensate for the elevated risk exposure and uncertainty associated with the Borrowers' increased health risk.

The main hypothesis is as follows: The occurrence of carcinogen exposure leads to a corresponding rise in the mortgage rate spread. This hypothesis assumes that lenders possess more bargaining power and better access to information compared to borrowers. This assumption shapes the proposed relationship between carcinogen exposure and the adjustment of mortgage rate spreads.

# 2. Data and Summary Statistics

## 2.1. Mortgage Data

This research exploits the U.S. mortgage dataset which is publicly accessible through the Home Mortgage Disclosure Act (HMDA). Established in 1975, HMDA requires financial institutions to collect and report data pertaining to their mortgage lending activities, with the aim of addressing housing discrimination and ensuring fair lending practices. The HMDA dataset encompasses a wealth of information, including details about loan rates, rate spreads, loan purposes (whether for property purchase or refinancing), loan amounts, property values, the identity of mortgage originators, and the relevant regulatory agencies. It also contains certain borrower-specific information such as applicants' gender, race, age and income levels.

Additionally, the HMDA data includes information on whether a loan was transferred to a third-party entity, such as a Government-Sponsored Enterprise (GSE), during the reporting year. Notably, nonbank lenders predominantly channel their originations to GSEs, reflecting the limited role of private-label mortgage-backed securities in their lending operations.

I take a sample from the HMDA dataset based on the following criteria. First, since the availability of critical information, such as loan rate, rate spread, and loan cost, begins in 2018, my investigation is restricted in a specific timeframe from 2018 to 2021. Second, I focus exclusively on mortgages meeting the conforming loan limits. Conforming loans are mortgage loans that adhere to the loan limits and criteria set by government-sponsored enterprises (GSEs) like Fannie Mae and Freddie Mac, making them eligible for purchase in the secondary mortgage market. The second criterion is that the sample only includes 30-year fixed-rate mortgages. This term ensures that the mortgage lenders need to factor in long-term risks, such as environmental pollution and borrowers' health hazard, when pricing the mortgage. Additionally, by removing the outliers at the top and bottom 0.1% and keeping the non-missing values, I ensure that the mortgage data have sensible distributions in terms of income, property value and interest rate. Finally, to address the possible measurement errors in data, all observations with a loan-to-value ratio above 100% are excluded.

## 2.2. Toxic Release Data

The TRI database has data on the volumes, categories, and routes of release for hazardous substances discharged by reporting facilities, along with the geographical coordinates of these facilities. The data spans from 1987 to the present, and for the latest dataset of 2021 in my sample, there are 17686 unique facilties and 540 types of chemicals. Besides information related to the facility's chemical release such as routes of release and release amount, this research also utilises the carcinogenic classification for each facility-chemical observation provided by the EPA. All the chemicals classified as "carcinogenic" in the TRI database follow the reporting requirements of the Occupational Safety and Health Administration (OSHA), in which chemicals are only required to be reported if they exceed "de minimis" concentrations in a mixture. By combining the carcinogenic classification information with the total release amount of each chemical, I can calculate the amount of facility-level and county-level carcinogenic releases.

However, it should be noted that not all facilities consistently report each year, with factors such as the cessation of production activities, reductions in chemical quantities falling below thresholds, or alterations in production processes contributing to this variability. I do not remove the discontinued facilities from the sample, but rather each facility as continuously operational between the first and last observed years, to ensure the most accurate measurement of county-level carcinogen exposure.

The data wrangling process also involves joining the toxic releases data from the TRI with mortgage data from HMDA to create a panel, using the county Federal Information Processing Standards (FIPS) code as the common identifier. This process relies on regex pattern matching to establish a FIPS code variable based on county and state names provided in the TRI dataset. Some counties do not align perfectly in the final panel, resulting in mismatches, and certain observations are excluded due to alterations in geographical administrative units. For instance, the Valdez–Cordova Census Area, located in Alaska, USA, under ZIP code 99686, was removed from the dataset following an administrative restructuring on January 2, 2019, which saw the division of the Valdez–Cordova Census Area into the Chugach Census Area and the Copper River Census Area.

## 2.3. Summary statistics

Table 1 provides summary statistics for all sample variables, divided by county-level and loan-level variables. The primary dataset encompasses a substantial 977,922 originated mortgages distributed across a diverse landscape of 1,829 counties within the United States.

The upper part of the summary table shows county-level variables from the TRI such as total carcinogen releases, and total non-carcinogen releases. These variables exhibit significant variations, indicating diverse environmental and geographical conditions. Figure 2 provides a graphical illustration of the spatial distribution of the TRI's facilities.

Conversely, delving into the loan-level variables sourced from HMDA dataset unveils variations in mortgages and borrowers' characteristics. Variables such as interest rates, rate spreads, loan-to-value ratios, and property values showcase noticeable distinctions, underscoring the diverse financial dynamics prevalent within the housing market. Figure 2 supplements the statistics by visually portraying the divergence in county-level mortgage rate spreads across the United States.

Table 1 further provides insights into log-transformed variables encompassing toxic release metrics, property values, and income. This transformation was necessitated by the highly skewed distributions inherent in these variables.

Carcinogen-released facility • No ▲ Yes
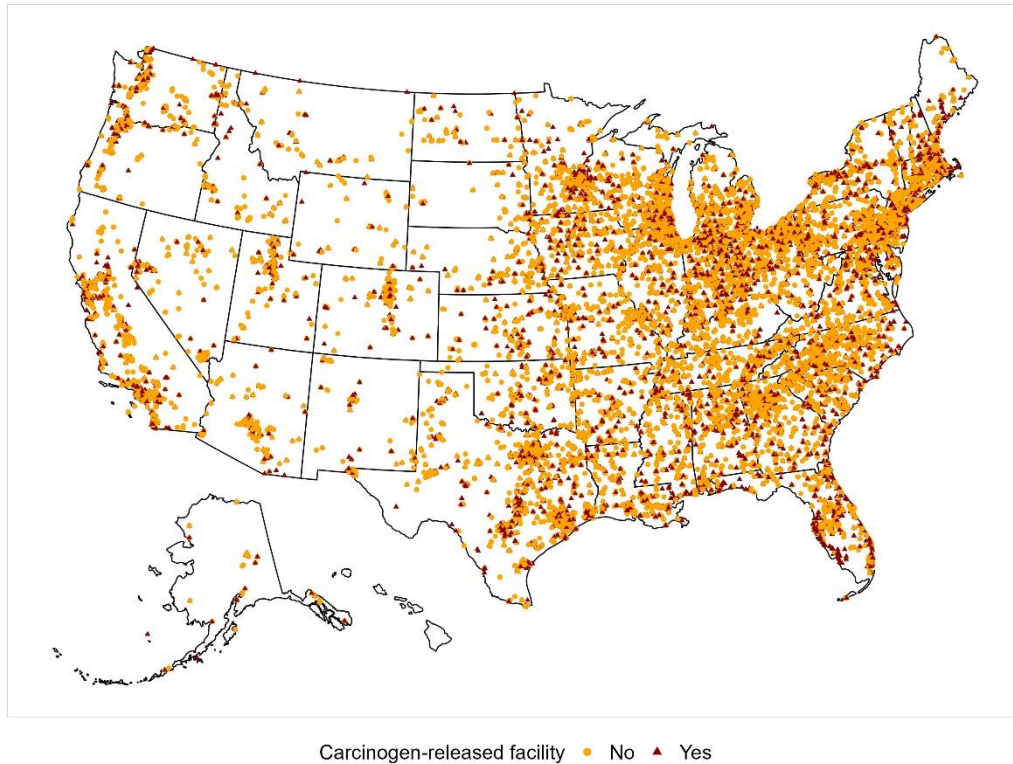
**Figure 1:** Locations of carcinogenic and non-carcinogenic TRI facilities in 2021.
Round and yellow dots represent non-carcinogen released facilities while triangle-shaped and red dots represent carcinogen released facilities.
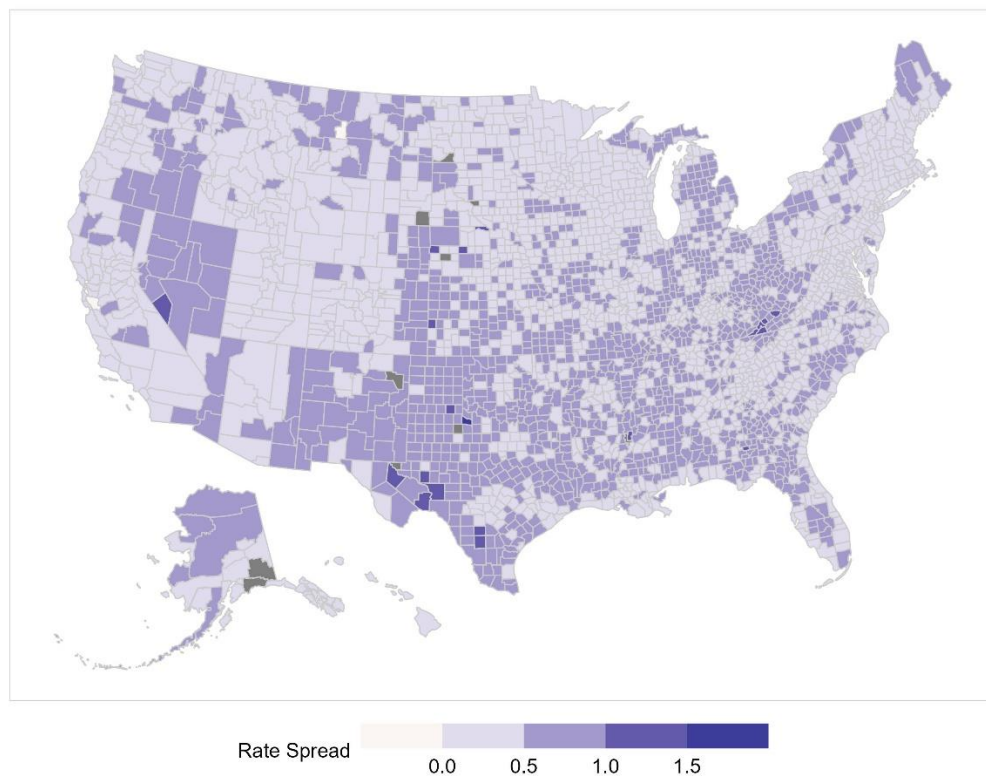


Rate Spread    0.0    0.5    1.0    1.5

**Figure 2**: Distribution of mortgage rate spread from HMDA dataset at the county level.
Average county-level rate spread is divided into 5 levels. In gray are counties with HMDA observations.

**Table 1:** Summary statistics

This table shows the summary statistics for the variables used in this research. The sample includes 997,922 observations of HMDA loan mortgage at 1,829 U.S. counties, throughout 4 years from 2018 to 2021. The descriptions of the variables are provided in the Appendix.

| | Mean | SD | p25 | p50 | p75 | Min | Max |
|---|---|---|---|---|---|---|---|
| **County-level variables** | | | | | | | |
| Total Carcinogen Releases ('000 Pounds) | 334.20 | 1839.03 | 3.59 | 40.39 | 131.01 | 0.00 | 39200.00 |
| Ln(Total Carcinogen Releases) | 9.76 | 3.29 | 8.29 | 10.62 | 11.78 | -8.52 | 17.48 |
| Total Non-carcinogen Releases ('000 Pounds) | 3559.19 | 17600.00 | 74.60 | 340.54 | 1291.60 | 0.00 | 275000.00 |
| Ln(Total Non-carcinogen Releases) | 12.51 | 2.67 | 11.29 | 12.76 | 14.09 | -10.13 | 19.43 |
| Total Carcinogen Air Releases ('000 Pounds) | 92.82 | 278.08 | 0.69 | 19.81 | 65.65 | 0.00 | 2277.02 |
| Ln(Total Carcinogen Air Releases) | 8.69 | 3.51 | 6.54 | 9.89 | 11.09 | 0.00 | 14.64 |
| Land Area (km2) | 2370.00 | 3120.00 | 1070.00 | 1560.00 | 2360.00 | 5.30 | 47100.00 |
| Housing Density (Housing units per mil2) | 947.19 | 2640.29 | 168.22 | 458.22 | 820.15 | 0.38 | 40339.00 |
| Unemployment Rate (%) | 4.90 | 2.19 | 3.40 | 4.20 | 5.90 | 1.30 | 17.80 |
| **Loan-level variables (from HMDA)** | | | | | | | |
| Rate Spread (%) | 0.36 | 0.53 | 0.02 | 0.27 | 0.59 | -2.94 | 4.37 |
| Interest Rate (%) | 3.82 | 0.86 | 3.12 | 3.75 | 4.50 | 1.79 | 8.37 |
| Loan-to-Value ratio | 0.78 | 0.16 | 0.70 | 0.80 | 0.91 | 0.00 | 6.20 |
| Income ('000 USD) | 113.38 | 78.61 | 61.00 | 93.00 | 140.00 | 1.00 | 711.00 |
| Ln(Income) | 11.45 | 0.62 | 11.03 | 11.44 | 11.85 | 6.91 | 13.47 |
| Property value ('000 USD) | 395.81 | 254.50 | 225.00 | 335.00 | 485.00 | 55.00 | 2295.00 |
| Ln(Property value) | 12.72 | 0.59 | 12.32 | 12.72 | 13.09 | 10.92 | 14.65 |
| Bank (Bank = 1) | 0.15 | 0.36 | 0 | 0 | 0 | 0 | 1 |
| Loan purpose (Refinancing = 1) | 0.39 | 0.49 | 0 | 0 | 1 | 0 | 1 |
| Applicants' Age (from 25 to 75 y-o, into 7 levels) | 3.44 | 1.36 | 2 | 3 | 4 | 1 | 7 |
| Applicants' Gender (Female/Male/Joint) | 2.10 | 0.79 | 1 | 2 | 3 | 1 | 3 |

# 3. Empirical Strategy

## 3.1. Main variables of interest

The carcinogen exposure level is measured by aggregating facility-level release indicators, reported in the Toxic Release Inventory. These indicators encompass three broad categories: *On-site Release Total*, representing the quantity of toxic chemicals released at the facility itself; *Off-site Release Total*, indicating the quantity of toxic chemicals transferred to off-site locations for release or disposal; and *Total Release*, which combines both *On-site* and *Off-site* totals. By combining this data with the Carcinogen classification from the TRI, I can calculate the amount of carcinogenic and non-carcinogenic waste generated by each facility. Subsequently, I utilize the geographical identifiers of these facilities to consolidate annual county-level data on toxic chemical waste releases.

For the main analysis, *Total Carcinogen Release* is used to measure the carcinogen exposure in a county and use the *Total Carcinogen Air Release* for robustness check. Additionally, I created the *Carcinogen Exposure Dummy* variable by splitting the main *Total Carcinogen Release* into "High" release and "Low" release based on the median value.

The dependent variable is the mortgage rate spread obtained from the Home Mortgage Disclosure Act dataset. The spread is the difference between the interest rate that mortgage lenders charge to borrowers and the low-risk interest rate. A mortgage with a wider rate spread indicates that the lender perceives the mortgage as having relatively higher risk, and reversely.

I also delve into a second target variable, the mortgage interest rate. While the rate spread signifies the marginal cost, the interest rate represents the direct expense of borrowing and the potential return on lending or investing funds. Consequently, employing the interest rate allows me to examine how carcinogen exposure influences the fundamental pricing mechanisms of lenders.

## 3.2. Empirical model

This study aims to measure the relationship between properties' exposure to carcinogenic waste (at the county level), and cost of mortgage credit. However, the key empirical problem is that variation in the mortgage rate spreads might be explained by factors other than carcinogen exposures. For instance, properties near manufacturing facilities usually have lower prices (Mastromonaco, 2015), which attracts low-income and less creditworthy home buyers. *Figure 1* gives a conceptual illustration of factors involved in the relationship between carcinogenic waste and mortgage interest rate spread.
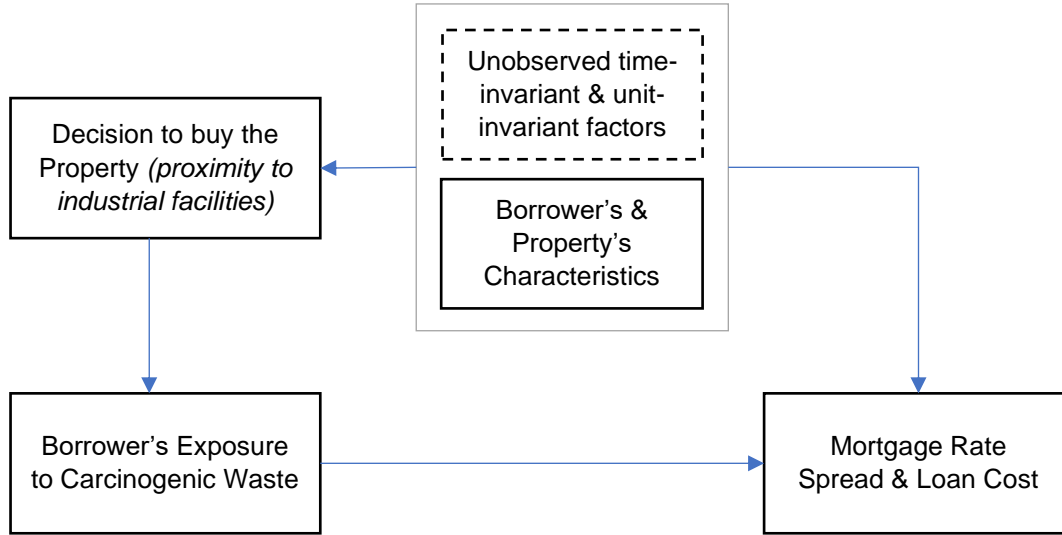
**Figure 3:** Conceptual representation of the involved factors in the relationship between carcinogenic waste and mortgage interest rate spread.
*(Dashed boxes indicate unobserved factors)*

I use the fixed effects models to address the confounding problem related to unobserved county-specific, time-specific, and lender-specific variables. The aim of the model is to compare mortgages that have observable similarities in loan details, properties' characteristics, and borrowers' characteristics. This means including in the regression a set of covariates that can control for the main traits of loans, properties, and borrowers. The regression estimation is of the following form:

$$\{Rate\ Spread\}_{izt} = \{Carcinogens\ Exposure\}_{zt}\beta_1 + X'_{it}\beta_2 + \gamma_t + c + \epsilon_{it} \quad (1)$$

$$\{Loan\ Cost\}_{izt} = \{Carcinogens\ Exposure\}_{zt}\beta_1 + X'_{it}\beta_2 + \gamma_t + c + \epsilon_{it} \quad (2)$$

Whereas the dependent variable {Rate Spread} is the difference between the covered loan's annual percentage rate of mortgage $i$ originated in year $t$ in county $z$, and the average prime offer rate for a similar transaction, determined on the date when the interest rate is established. The {Loan Cost} is measured using the interest rate for the covered loan. The {Carcinogen Exposure} is calculated using the log-transformed total carcinogenic release of county $z$ in year $t$.

$X'_{it}$ include a set of variables controlling for different characteristics of mortgage, property, and borrower. The mortgage-level variables include *Loan Purpose* (a dichotomous variable equals 1 if the loan is for refinancing and 0 if the loan is for buying a new house), *Bank (*a dichotomous variable equals if the loan's originated lender is a bank, and 0 if the loan it is a non-bank lender) and *Loan-to-Value ratio* (the mortgage's loan-to-value ratio). The variables controlling for property characteristics are *Property Value* and *Metro Dummy* (which specify whether the property is in an urban or rural census tract). Finally, the borrower-level variables include applicants' *Income, Gender, Age,* and *Race* in combination with the aforementioned *Loan-to-Value* ratio, which can jointly account for the borrower's creditworthiness. Variable *Gender* specifies whether the applicants are only female, only male, or both. *Age* is a factor variable that divides the age range from below 25 to above 74 years old into 7 levels. *Race* is also a factor variable that specifies

whether the main applicant is White, Asian, African American, or other ethnicities. In addition, I also include several county-level variables including *Land Area*, *Housing Density* and *Unemployment Rate* to control for the county's socio-demographic conditions.

I include the year and state fixed effects, to account for the local economic conditions and regulatory environments, as well as the interacted fixed effects of year and state, to allow the effect of each state to vary depending on time. In addition, I use the lender's identification from the HMDA and include a lender fixed effects in further analyses, to capture the different characteristics of lenders.

Notably, while the main independent variable {Carcinogen Exposure} is aggregated at the county level, the target variables {Rate Spread} and {Interest Rate}, and most of the set of covariates X are at the individual level. This means that, though I try to exploit the variation of carcinogen exposure between different counties (i.e., the different amounts of carcinogenic waste released in counties), the individual-level data can provide additional variation to analyse the heterogenous effect of carcinogen exposure on different groups of borrowers and properties.

# 4. Main results

## 4.1. Baseline results

Table 2 shows the baseline regression results exploring the effects of Carcinogen Exposure on the mortgage rate spread (columns 1 to 3) and mortgage interest rate (columns 4 to 5). For each dependent variable, I use Year fixed effect, State fixed effect, and interaction term of both, with the descriptions of each specification at the bottom of the table.

For the regressions with mortgage rate spread shown in the first 3 columns, the coefficient estimates of Carcinogen Exposure are consistently positive and statistically significant across all specifications, showing that mortgages for properties with higher exposure to carcinogens tend to have higher mortgage interest rate spreads. However, the effect magnitude is modest with the coefficient estimate standing at 0.004 for both fixed effects specifications. This translates into a 0.0042 bps premium in mortgage rate spread when the amount of county-level carcinogenic waste increases by 10%. Using the statistics in the sample, the mortgage interest rate premium between a county with average level of carcinogen exposure compared to a zero-exposure county is 1.52 bps.

However, given the variance of the carcinogen releases between different countries, the effect might be more significant. For example, within the state of Texas in 2021, the interest rate spread of mortgages in Jefferson County (FIPS code 48245) is approximately 2.72 bps higher than in Wichita County (FIPS code 48485) due to higher carcinogenic exposure. This discrepancy translates to an additional financing cost of around $2,000 for the typical borrower in my sample, with a loan amount of $300,000 and a 30-year term.

Instead of pricing the carcinogenic risks into loan spreads, lenders could opt for charging higher fixed costs during the loan origination process. Therefore, in the second set of regression analyses, I use an additional dependent variable – mortgage interest rate - to measure the cost of the loans, as shown in columns (3) and (4) of Table 2. Notably, the coefficient estimates in both fixed effects specifications demonstrate a statistically significant positive relationship. Comparing the magnitude of these coefficients to the mortgage rate spread highlights that lenders tend to transfer a substantial portion of the carcinogen risk cost to borrowers by imposing a premium (spread) atop the underlying interest rate. This outcome aligns with the hypothesis that lenders perceive carcinogen exposure as a long-term risk.

**Table 2:** Baseline result

This table shows the estimates from regressions of the mortgage spread or mortgage interest rate on the Carcinogen Exposure, with a set of covariates controlling for the characteristics of loan, borrower, and property. Columns (1), (2), and (3) show the effect of carcinogen exposure on mortgage rate spread, while columns (4), (5), and (6) show the effect on mortgage interest rates. The main independent variable Carcinogen Exposure is measured by the Total Carcinogen Release. Total Carcinogenic Releases, Income, and Property Value are log-transformed.

*Standard errors clustered at the county level are reported in parentheses under the coefficients. \*\*\*, \*\*, and \* indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable | Rate Spread | Rate Spread | Interest Rate | Interest Rate |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Carcinogen Exposure | 0.004** | 0.004*** | 0.001* | 0.003** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Loan Purpose | 0.053*** | 0.053*** | 0.073*** | 0.017*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Bank | 0.013 | 0.013 | -0.000 | 0.007 |
| | (0.011) | (0.011) | (0.023) | (0.008) |
| Loan-to-Value Ratio | -2.021*** | -2.019*** | -2.439*** | -0.113** |
| | (0.068) | (0.068) | (0.068) | (0.057) |
| Loan-to-Value Ratio$^2$ | 1.797*** | 1.797*** | 2.103*** | 0.158*** |
| | (0.052) | (0.051) | (0.047) | (0.044) |
| Age | 0.068*** | 0.068*** | 0.047*** | 0.059*** |
| | (0.003) | (0.003) | (0.002) | (0.004) |
| Age$^2$ | -0.007*** | -0.007*** | -0.004*** | -0.006*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Income | -0.360*** | -0.359*** | -0.321*** | -0.339*** |
| | (0.053) | (0.053) | (0.034) | (0.055) |
| Income$^2$ | 0.018*** | 0.018*** | 0.017*** | 0.017*** |
| | (0.002) | (0.002) | (0.002) | (0.002) |
| Male | -0.003 | -0.003 | 0.000 | -0.006** |
| | (0.003) | (0.003) | (0.002) | (0.003) |
| Race: Asian vs. White | -0.051*** | -0.051*** | -0.043*** | -0.064*** |
| | (0.006) | (0.006) | (0.003) | (0.006) |
| Race: Black vs. White | 0.110*** | 0.110*** | 0.104*** | 0.084*** |
| | (0.004) | (0.004) | (0.003) | (0.004) |
| Race: Natives vs. White | 0.053*** | 0.053*** | 0.049*** | 0.039*** |
| | (0.004) | (0.004) | (0.003) | (0.004) |
| Property Value | -0.327*** | -0.327*** | -0.333*** | -0.265*** |
| | (0.011) | (0.011) | (0.007) | (0.009) |
| Metropolitan | 0.022*** | 0.021*** | 0.021*** | 0.018*** |
| | (0.006) | (0.006) | (0.004) | (0.005) |
| County Land Area | -0.000 | -0.000 | -0.000 | -0.000* |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Hou. Density | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Unemp. Rate | 0.012*** | 0.016*** | 0.010*** | 0.011** |
| | (0.005) | (0.003) | (0.002) | (0.005) |
| County Non-carc Waste | -0.003 | -0.003* | -0.001 | -0.002* |
| | (0.002) | (0.002) | (0.001) | (0.001) |
| Year Fixed Effect | Yes | No | No | Yes |
| State Fixed Effect | Yes | No | No | Yes |
| Year×State Fixed Effect | No | Yes | Yes | No |
| Number of Obs. | 975,916 | 975,916 | 975,719 | 975,916 |
| Adjusted R$^2$ | 0.245 | 0.248 | 0.395 | 0.668 |

The coefficient estimates for the control variables further reinforce the anticipated associations between mortgage characteristics and the cost of mortgage credit. Borrowers with higher income, elevated loan-to-value ratios, purchasing more valuable properties, and residing outside metropolitan areas tend to incur lower mortgage rate spreads and interest rates. Furthermore, squared terms for Age, Income, and Loan-to-Value Ratio are included to explore potential nonlinear relationships with mortgage interest rates. The opposing signs and magnitudes of these squared terms indicate diminishing relationships between Age, Income, Loan-to-Value Ratio, and the cost of credit. Additionally, the analysis suggests that mortgage interest rate pricing does not significantly differ between bank and non-bank lenders, while the loan's purpose (refinancing or new purchase) exerts a statistically significant effect. Both are investigated further in the additional analysis.

## 4.2. Robustness tests

I conducted two robustness checks to ensure the validity of the primary analysis. The first robustness check uses the same fixed effects models and most of the specifications, with only changes in the dependent variables and the independent variable of interest. Specifically, I replace the HMDA's Rate Spread variable with an alternative variable US30Y Spread, which uses the U.S. 30-Year Treasury Yield as the base interest rate to calculate the rate spread. The U.S. Treasury bonds are widely considered as nearly risk-free financial assets as they are fully backed by the U.S. government, and I use the 30-year Treasury bond as it matches with the maturity of the mortgages in my sample. For the main independent variable Carcinogen Exposure, I use the alternative variable Total Carcinogen Air Releases from the Toxic Release Inventory, instead of the Total Carcinogen Releases. Numerous toxic pollutants are difficult to detect because they lack visible or odour-based indicators, making them less noticeable than other harmful external factors (Currie et al., 2015), yet air pollution is a major cause of lung cancer – one of the most common types of cancer. These factors make air pollution the research target of many health economics papers (Calderón-Garcidueñas & Ayala, 2023; Currie et al., 2015; Nafstad et al., 2003).

The estimation results of my robustness check are provided in Table 3. It can be seen from columns (1) to (4) that the coefficients of the main independent variable of interest are positive and statically significant at the 5% level throughout all regressions, although the magnitude is slightly different compared to the baseline result in Table 2. The result continues to suggest that higher exposure to carcinogens in the air is associated with increased mortgage interest rate spreads.

**Table 3:** Robustness test with alternative variables

This table shows the estimates from regressions of the alternative mortgage spread or mortgage interest rate on the alternative Carcinogen Exposure with a set of covariates controlling for the characteristics of loan, borrower, and property. Columns (1) (2) show the effect of carcinogen exposure on the mortgage rate spread, while columns (4) (5) show the effect on mortgage interest rates. The alternative mortgage rate spread is measured by the difference between the mortgage rate and the U.S. 30-year Treasury Yield. The alternative Carcinogen Exposure is measured by the Total Carcinogen Air Release. Total Carcinogen Air Releases, Income, and Property Value are log-transformed.

*Standard errors clustered at the county level are reported in parentheses under the coefficients. \*\*\*, \*\*, and \* indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable | US30Y Spread (1) | US30Y Spread (2) | Interest Rate (3) | Interest Rate (4) |
|---|---|---|---|---|
| Carcinogen Air Exposure | 0.002** | 0.002** | 0.001** | 0.002** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Loan Purpose | 0.017*** | 0.018*** | 0.031*** | 0.017*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Bank | 0.007 | 0.007 | -0.137*** | 0.007 |
| | (0.008) | (0.008) | (0.021) | (0.008) |
| Loan-to-Value Ratio | -0.113** | -0.106* | -0.309*** | -0.113** |
| | (0.057) | (0.056) | (0.044) | (0.057) |
| Loan-to-Value Ratio$^2$ | 0.157*** | 0.153*** | 0.288*** | 0.157*** |
| | (0.044) | (0.043) | (0.034) | (0.044) |
| Age | 0.059*** | 0.058*** | 0.041*** | 0.059*** |
| | (0.004) | (0.003) | (0.003) | (0.004) |
| Age$^2$ | -0.006*** | -0.006*** | -0.003*** | -0.006*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Income | -0.343*** | -0.336*** | -0.166*** | -0.343*** |
| | (0.055) | (0.055) | (0.041) | (0.055) |
| Income$^2$ | -0.007** | -0.007** | -0.004* | -0.007** |
| | (0.003) | (0.003) | (0.002) | (0.003) |
| Male | 0.009*** | 0.008*** | 0.015*** | 0.009*** |
| | (0.003) | (0.003) | (0.002) | (0.003) |
| Race: Asian vs. White | -0.064*** | -0.063*** | -0.056*** | -0.064*** |
| | (0.006) | (0.006) | (0.003) | (0.006) |
| Race: Black vs. White | 0.085*** | 0.085*** | 0.073*** | 0.085*** |
| | (0.004) | (0.004) | (0.003) | (0.004) |
| Race: Natives vs. White | 0.040*** | 0.039*** | 0.033*** | 0.040*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Property Value | -0.265*** | -0.264*** | -0.266*** | -0.265*** |
| | (0.009) | (0.009) | (0.006) | (0.009) |
| Metropolitan | 0.017*** | 0.016*** | 0.010*** | 0.017*** |
| | (0.005) | (0.005) | (0.003) | (0.005) |
| County Land Area | -0.000* | -0.000* | -0.000 | -0.000* |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Hou. Density | 0.000 | -0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Unemp. Rate | 0.012** | 0.015*** | 0.009*** | 0.012** |
| | (0.005) | (0.003) | (0.002) | (0.005) |
| County Non-carc Waste | -0.002 | -0.002* | -0.001 | -0.002 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Year Fixed Effect | Yes | No | No | Yes |
| State Fixed Effect | Yes | No | No | Yes |
| Year×State Fixed Effect | No | Yes | Yes | No |
| Number of Obs. | 981,220 | 981,220 | 981,024 | 981,220 |
| Adjusted R$^2$ | 0.300 | 0.304 | 0.395 | 0.667 |

**Table 4:** Robustness Test with Propensity Score Matching

This table shows the estimate of the Average Treatment Effect on the Untreated (ATU), by matching mortgages in counties with zero carcinogen exposure (control/untreated group) with mortgages in counties with positive carcinogen exposure (treatment group) based on characteristics of loans (loan purpose and loan-to-value ratio), borrowers (income, age, gender, race), location (U.S. region) and property value. The outcome model is matching, and the treatment model is logit.

*Abadie-Imbens standard errors are reported in parentheses under the coefficients.*
*\*\*\*, \*\*, and \* indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable: Mortgage Rate Spread | (1) |
| --- | --- |
| Carcinogen Exposure | 0.022*** |
| | (0.006) |
| Control Variables | Yes |
| Number of Observations | 101,164 |

To further strengthen the validity of the result, I use the propensity score matching method to reduce bias in the sample. Specifically, I use a propensity score matching based on logit regression, to match mortgages in counties with zero carcinogenic exposure (control/untreated group) and mortgages in counties with positive carcinogenic exposure (treatment group) based on characteristics of loans (Loan Purpose and Loan-to-Value Ratio decile bins, Property Value decile bins), borrowers (Income decile bins, Age, Gender, Race). It also requires that the matching is only made for two mortgages in the same U.S. region. In the end, the matching sample has 101,154 observations in 1613 counties across all 5 U.S regions. As shown in Table 4, the coefficient of the Carcinogen Exposure remains positive and statically significant at a 1% level.

Overall, the results of the robustness check provide a stronger ground for the main analysis, addressing the concern that my findings are primarily influenced by measurement errors and the unbalanced sample.

# 5. Additional Analyses

### 5.1.        Heterogeneity across races

The impact of environmental hazards on different racial groups has been a significant topic in environmental inequality research. Studies have shown that Black Americans are exposed to higher levels of air pollution, specifically fine particulate matter (PM2.5), compared to White Americans (Josey et al., 2023). Additionally, Laub (1999) finds that race emerges as the most influential factor in proximity to hazardous sites, surpassing income and other socio-economic metrics. Banzhaf et al. (2019) assess the environmental justice literature, particularly where it intersects with economic research, and examine four potential mechanisms contributing to observed patterns: uneven firm location, household exposure to environmental hazards, market coordination, and discriminatory politics/enforcement, and find the disproportionate exposure of minority communities to pollution. Concerning the impact of industrial pollution, research also finds that the connection between the racial composition of nearby communities and the location of industrial facilities is a challenging issue, and implementing land use planning restrictions on industrial development could emerge as a viable and efficient approach for safeguarding low-income and minority communities (Ahlers, 2016).

Therefore, I conduct a further analysis to look at the heterogenous effect of carcinogen exposure on the cost of mortgage credit between different racial groups. I focus on the differences between Black & African Americans and other ethnicities. As shown in Figure 4, Black & African Americans have substantially higher mortgage rate spread compared to Asians, White Americans and Native Americans.
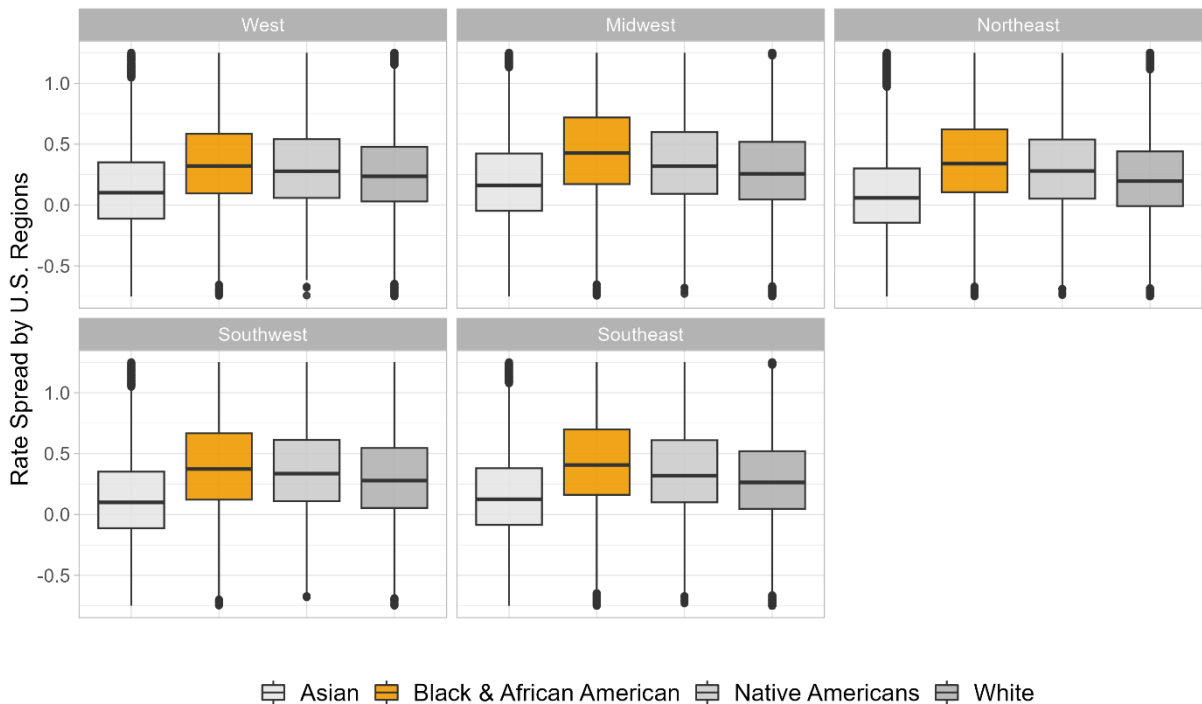


**Figure 4:** Mortgage interest rate spread by different ethnic groups in different U.S. regions.

Table 5 provides a detailed examination of the environmental racial issue through regression estimates. First, the results continue to indicate that there is a statistically significant relationship between Carcinogen Exposure and the variables Rate Spread and Interest Rate, as evidenced by the low p-value. Furthermore, the results show that the coefficient estimate of the variable Black - – a dummy variable created from the applicant's race in the HMDA, indicating whether the mortgage's main applicant is Black or African American – has a statistically significant relationship with both mortgage rate spread and interest Rate This implies that people in the Black & African American group are associated with higher rate spreads and interest rates, regardless of carcinogen exposure.

The main variable of interest in Table 5 is the interaction term between Carcinogen Exposure and Black. The interaction term shows a positive and statistically significant relationship with mortgage rate spread at the 5% confidence level, but not with interest rate. This suggests that the impact of carcinogen exposure on rate spread is modified by the applicant's racial groups. Specifically, the Black and African American groups experience a slightly higher mortgage credit premium associated with carcinogen exposure compared to other racial groups. Using the same example as in the Baseline Result, this effect can be translated into a 1.35 bps premium in mortgage interest rate per year.

This result adds to the collection of literature on the impact of the TRI facilities on the racial composition of surrounding communities, providing further supporting evidence on the issue of environmental inequality.

**Table 5:** Additional Analysis – Black vs. Non-black Borrowers

This table shows the estimates from regressions of the mortgage spread or mortgage interest rate on the Carcinogen Exposure, the interaction term of Carcinogen Exposure with Black Dummy, with a set of covariates controlling for the characteristics of loan, borrower, and property. Columns (1) (2) show the effect of carcinogen exposure on mortgage rate spread, while columns (4) (5) show the effect on mortgage interest rates. The variable Black is a dichotomous variable, with the value of 1 indicating Black & African American borrowers. Income and Property Value are log-transformed.

*Standard errors clustered at the county level are reported in parentheses under the coefficients. ***, **, and * indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable | Rate Spread (1) | Rate Spread (2) | Interest Rate (3) | Interest Rate (4) |
|---|---|---|---|---|
| Carcinogen Exposure | 0.003** | 0.003** | 0.003** | 0.003** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Carc.Exposure×Black | 0.002** | 0.002** | 0.000 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Black | 0.089*** | 0.088*** | 0.081*** | 0.080*** |
| | (0.011) | (0.011) | (0.011) | (0.011) |
| Loan Purpose | 0.053*** | 0.053*** | 0.017*** | 0.018*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Bank | 0.013 | 0.013 | 0.007 | 0.007 |
| | (0.011) | (0.011) | (0.008) | (0.008) |
| Loan-to-Value Ratio | -2.020*** | -2.019*** | -0.113** | -0.105* |
| | (0.068) | (0.068) | (0.057) | (0.056) |
| Loan-to-Value Ratio$^2$ | 1.797*** | 1.797*** | 0.158*** | 0.153*** |
| | (0.052) | (0.051) | (0.044) | (0.043) |
| Age | 0.068*** | 0.068*** | 0.059*** | 0.058*** |
| | (0.003) | (0.003) | (0.004) | (0.003) |
| Age$^2$ | -0.007*** | -0.007*** | -0.006*** | -0.006*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Income | -0.359*** | -0.358*** | -0.339*** | -0.332*** |
| | (0.053) | (0.053) | (0.055) | (0.055) |
| Income$^2$ | 0.018*** | 0.018*** | 0.017*** | 0.017*** |
| | (0.002) | (0.002) | (0.002) | (0.003) |
| Male | -0.003 | -0.003 | -0.006** | -0.007** |
| | (0.003) | (0.003) | (0.003) | (0.003) |
| Race: Asian vs. White | -0.052*** | -0.051*** | -0.064*** | -0.063*** |
| | (0.006) | (0.006) | (0.006) | (0.006) |
| Race: Natives vs. White | 0.053*** | 0.053*** | 0.039*** | 0.039*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Property Value | -0.327*** | -0.327*** | -0.265*** | -0.264*** |
| | (0.011) | (0.011) | (0.009) | (0.009) |
| Metropolitan | 0.022*** | 0.021*** | 0.018*** | 0.017*** |
| | (0.006) | (0.006) | (0.005) | (0.005) |
| County Land Area | -0.000 | -0.000 | -0.000* | -0.000* |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Housing Density | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Unemp. Rate | 0.012*** | 0.016*** | 0.011** | 0.014*** |
| | (0.005) | (0.003) | (0.005) | (0.003) |
| Other Non-carc Waste | -0.003 | -0.003* | -0.002* | -0.003** |
| | (0.002) | (0.002) | (0.001) | (0.001) |
| Year Fixed Effects | Yes | No | Yes | No |
| State Fixed Effects | Yes | No | Yes | No |
| Year×State Fixed Effects | No | Yes | No | Yes |
| Number of Observations | 975,916 | 975,916 | 975,916 | 975,916 |
| Adjusted R$^2$ | 0.245 | 0.248 | 0.668 | 0.669 |

## 5.2.    Heterogeneity across types of lenders

It is undeniable that the effects of carcinogen risk are placed upon mortgages regardless of the type of lender. However, as lenders have different exposure and capabilities to calculate and incorporate carcinogen risk, significant heterogeneity could exist between lenders. Furthermore, the US mortgage market is serviced by two distinct categories of lenders: banks and nonbanks, which have considerable differences in both long-term and short-term risk appetite, which could also intervene in the relationship between carcinogen risk and the cost of mortgage credit. In this analysis, I examine the heterogeneous effects across bank and non-bank lenders in the relationship between carcinogen risk and mortgage rate.

Following Buchak, Matvos, Piskorski and Seru (2018) classification, I designate traditional depository institutions as banks, and non-depository institutions as nonbanks. Specifically, banks are all entities regulated by the Federal Reserve System (FRB), Federal Deposit Insurance Corporation (FDIC), and the Office of the Comptroller of the Currency (OCC), as they offer credit intermediary services and accept deposits. This classification encompasses federally-chartered banks, state-chartered banks, and credit unions. In contrast, nonbanks provide credit intermediation services but do not accept deposits, thus operating under the sight of different regulators. Nonbanks primarily include Fintech lenders, and it's noteworthy that banks generally face more regulatory scrutiny compared to nonbanks.

Regarding business activities, nonbank lenders predominantly engage in the origination of mortgages intended for sale to Government-Sponsored Enterprises (GSEs). Banks, while also involved in originating mortgages for GSEs, allocate a smaller proportion of their loans for sale. In contrast to nonbanks, banks primarily originate a higher fraction of mortgages to retain on their own balance sheets. This practice aligns with the originate-to-distribute model, where originators have the capacity to offload a substantial portion of the associated costs and risks onto GSEs. GSEs, given their economies of scale, can manage the costs and subsequently pass on the cost-saving benefits to loan sellers. In addition, banks typically exhibit a propensity for gathering a more extensive array of data compared to their nonbank counterparts (Gupta et al., 2023). This can provide bank lenders with an informational advantage in pricing carcinogen risk into the credit cost of mortgages.
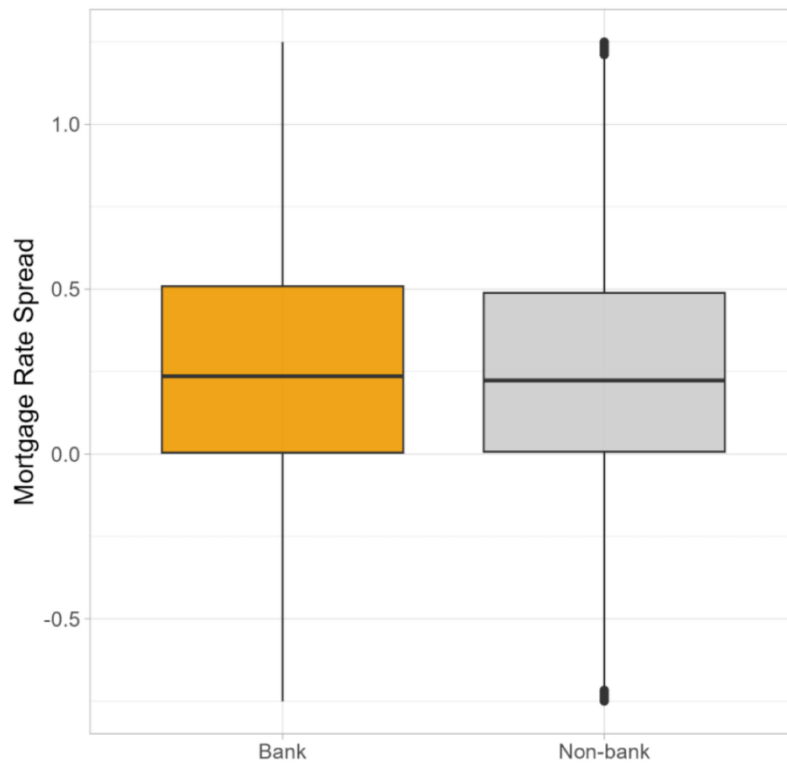
**Figure 5:** Boxplot comparing mortgage rate spread between bank and non-bank lenders.

To test the conjecture that the carcinogen risk has different effects on banks and non-bank lenders, I add the interaction of the Bank dummy variable and the Carcinogen Exposure. In addition, the difference in regulatory agencies might lead to different lender characteristics and regulatory expenses. Therefore, I also include lender-fixed effects in the subsequent regression analyses.

Table 6 shows the regression estimates when factoring in the differences between Bank and Nonbank lenders. The coefficient estimates of Carcinogen Exposure, in the context of rate spread in columns (1) and (2), exhibit a positive and statistically significant effect, although the magnitude is smaller than the baseline result. A similar trend is observed in the interest rate (columns (3) and (4)) with positively significant coefficients. This shows that when accounting for the unobserved and time-invariant characteristics of lenders, the effect of carcinogen risk on the cost of mortgage credit remains.

However, the interaction term of Carcinogen Exposure and Bank appears to have minimal impact across all models, with coefficients close to zero and statistically insignificant, signifying that the relationship between carcinogen exposure and the lending variables does not substantially differ between banks and non-banks. Table 6 also shows that the difference in rate spreads between banks and non-banks is insignificant, as also shown by Figure 2.

**Table 6:** Additional analysis – Bank and Non-bank Lenders

This table shows the estimates from regressions of the mortgage spread or mortgage interest rate on the Carcinogen Exposure, the interaction term of Carcinogen Exposure and Bank dummy, with a set of covariates controlling for the characteristics of loan, borrower, and property. Columns (1) (2) show the effect of carcinogen exposure on mortgage rate spread, while columns (4) (5) show the effect on mortgage interest rates. The variable Bank is a dichotomous variable, with value 1 indicating bank lenders and 0 indicating non-bank lenders. Income and Property Value are log-transformed.

*Standard errors clustered at the county level are reported in parentheses under the coefficients. \*\*\*, \*\*, and \* indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable | Rate Spread | Rate Spread | Interest Rate | Interest Rate |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Carcinogen Exposure | 0.004*** | 0.001* | 0.003*** | 0.002** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Carc.Exposure×Bank | 0.000 | 0.001 | 0.000 | 0.001 |
| | (0.002) | (0.001) | (0.002) | (0.001) |
| Bank | 0.010 | -0.006 | 0.007 | -0.144*** |
| | (0.022) | (0.024) | (0.016) | (0.023) |
| Loan Purpose | 0.053*** | 0.073*** | 0.018*** | 0.031*** |
| | (0.004) | (0.004) | (0.004) | (0.004) |
| Loan-to-Value Ratio | -2.019*** | -2.439*** | -0.106* | -0.310*** |
| | (0.068) | (0.068) | (0.056) | (0.044) |
| Loan-to-Value Ratio$^2$ | 1.797*** | 2.103*** | 0.153*** | 0.289*** |
| | (0.051) | (0.047) | (0.043) | (0.034) |
| Age | 0.068*** | 0.047*** | 0.058*** | 0.041*** |
| | (0.003) | (0.002) | (0.003) | (0.003) |
| Age$^2$ | -0.007*** | -0.004*** | -0.006*** | -0.003*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Income | -0.359*** | -0.321*** | -0.332*** | -0.160*** |
| | (0.053) | (0.034) | (0.055) | (0.041) |
| Income$^2$ | 0.018*** | 0.017*** | 0.017*** | 0.010*** |
| | (0.002) | (0.002) | (0.003) | (0.002) |
| Male | -0.003 | 0.000 | -0.007** | -0.004** |
| | (0.003) | (0.002) | (0.003) | (0.002) |
| Race: Asian vs. White | -0.051*** | -0.043*** | -0.063*** | -0.056*** |
| | (0.006) | (0.003) | (0.006) | (0.003) |
| Race: Black vs. White | 0.110*** | 0.104*** | 0.084*** | 0.073*** |
| | (0.004) | (0.003) | (0.004) | (0.003) |
| Race: Natives vs. White | 0.053*** | 0.049*** | 0.039*** | 0.033*** |
| | (0.004) | (0.003) | (0.004) | (0.004) |
| Property Value | -0.327*** | -0.333*** | -0.264*** | -0.266*** |
| | (0.011) | (0.007) | (0.009) | (0.006) |
| Metropolitan | 0.021*** | 0.021*** | 0.017*** | 0.011*** |
| | (0.006) | (0.004) | (0.005) | (0.004) |
| County Land Area | -0.000 | 0.000 | -0.000* | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Housing Density | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Unemp. Rate | 0.016*** | 0.010*** | 0.014*** | 0.009*** |
| | (0.003) | (0.002) | (0.003) | (0.002) |
| County Non-carc Waste | -0.003* | -0.001 | -0.003** | -0.001 |
| | (0.002) | (0.001) | (0.001) | (0.001) |
| Year×State Fixed Effects | Yes | Yes | Yes | Yes |
| Lender Fixed Effects | No | Yes | No | Yes |
| Number of Observations | 975,916 | 975,719 | 975,916 | 975,719 |
| Adjusted R$^2$ | 0.248 | 0.395 | 0.669 | 0.713 |

### 5.3.     Heterogeneity across types of loan purposes

It is possible that mortgages with different purposes – refinance or purchase a new property – might have different impacts of carcinogen exposure on mortgage rates. Refinanced mortgages carry a greater default risk compared to new-purchase mortgages, regardless of whether the borrower extracted cash during the finance process or not (Tracy & Wright, 2016). In addition, as carcinogen exposure contains long-term risks, it is also plausible that individuals seeking to refinance their properties have been exposed differently compared to those purchasing new homes. In short, the distinction in motivations, timeframes and risk perception between property purchasers and refinancers might influence how the lenders factor carcinogen risk when pricing mortgage rates.

Therefore, in an additional analysis, I include the interaction term of Carcinogen Exposure with Loan Purpose, and the results are exhibited in Table 7. I also include lender fixed effects as lenders might target new mortgage purchase borrowers or refinancing borrowers differently. As the coefficient estimates show, Carcinogen Exposure continues to demonstrate a statistically significant and positive relationship with Rate Spread across all specifications. However, the interaction term between Carcinogen Exposure and Loan Purpose is not statistically significant in either model. This suggests that the varying effect of carcinogen exposure between different loan purposes does not significantly alter the relationship between carcinogen exposure and mortgage interest rates.

**Table 7:** Additional analysis – Refinancing vs. New purchase Loans

This table shows the estimates from regressions of the mortgage spread or mortgage interest rate on Carcinogen Exposure, the interaction term of Carcinogen Exposure and Loan Purpose, with a set of covariates controlling for the characteristics of loan, borrower, and property. Columns (1) (2) show the effect of carcinogen exposure on mortgage rate spread, while columns (4) (5) show the effect on mortgage interest rates. The variable Loan Purpose is a dichotomous variable, with the value of 1 indicating refinancing mortgages and 0 indicating new-purchase mortgages. Income and Property Value are log-transformed.

*Standard errors clustered at the county level are reported in parentheses under the coefficients. \*\*\*, \*\*, and \* indicate the statical significance at the 1%, 5%, and 10% levels, respectively.*

| Dependent Variable | Rate Spread (1) | Rate Spread (2) | Interest Rate (3) | Interest Rate (4) |
|---|---|---|---|---|
| Carcinogen Exposure | 0.004*** | 0.002** | 0.003** | 0.001 |
| | (0.002) | (0.001) | (0.001) | (0.001) |
| Carc.Exposure×Purpose | -0.002 | -0.002 | 0.001 | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Loan Purpose | 0.072*** | 0.089*** | 0.005 | 0.019* |
| | (0.012) | (0.010) | (0.012) | (0.011) |
| Bank | 0.013 | -0.000 | 0.007 | -0.137*** |
| | (0.011) | (0.023) | (0.008) | (0.022) |
| Loan-to-Value Ratio | -2.018*** | -2.438*** | -0.106* | -0.311*** |
| | (0.068) | (0.068) | (0.056) | (0.044) |
| Loan-to-Value Ratio$^2$ | 1.796*** | 2.102*** | 0.154*** | 0.290*** |
| | (0.051) | (0.047) | (0.043) | (0.034) |
| Age | 0.068*** | 0.047*** | 0.058*** | 0.041*** |
| | (0.003) | (0.002) | (0.003) | (0.003) |
| Age$^2$ | -0.007*** | -0.004*** | -0.006*** | -0.003*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Income | -0.359*** | -0.320*** | -0.332*** | -0.160*** |
| | (0.053) | (0.035) | (0.055) | (0.041) |
| Income$^2$ | 0.018*** | 0.017*** | 0.017*** | 0.010*** |
| | (0.002) | (0.002) | (0.003) | (0.002) |
| Male | -0.003 | 0.000 | -0.007** | -0.004** |
| | (0.002) | (0.002) | (0.003) | (0.002) |
| Race: Asian vs. White | -0.051*** | -0.043*** | -0.063*** | -0.056*** |
| | (0.006) | (0.003) | (0.006) | (0.003) |
| Race: Black vs. White | 0.110*** | 0.104*** | 0.084*** | 0.073*** |
| | (0.004) | (0.003) | (0.004) | (0.003) |
| Race: Natives vs. White | 0.053*** | 0.049*** | 0.039*** | 0.033*** |
| | (0.004) | (0.003) | (0.004) | (0.004) |
| Property Value | -0.327*** | -0.333*** | -0.264*** | -0.266*** |
| | (0.011) | (0.007) | (0.009) | (0.006) |
| Metropolitan | 0.021*** | 0.021*** | 0.017*** | 0.011*** |
| | (0.006) | (0.004) | (0.005) | (0.004) |
| County Land Area | -0.000 | -0.000 | -0.000* | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Housing Density | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| County Unemp. Rate | 0.016*** | 0.010*** | 0.014*** | 0.009*** |
| | (0.003) | (0.002) | (0.003) | (0.002) |
| County Non-carc Waste | -0.003* | -0.001 | -0.003** | -0.001 |
| | (0.002) | (0.001) | (0.001) | (0.001) |
| Year×State Fixed Effects | Yes | Yes | Yes | Yes |
| Lender Fixed Effects | No | Yes | No | Yes |
| Number of Observations | 975,916 | 975,719 | 975,916 | 975,719 |
| Adjusted R$^2$ | 0.248 | 0.395 | 0.669 | 0.713 |

# 6. Conclusion

Considering the economic risks associated with cancer is crucial for financial market participants, particularly in the housing sector. High carcinogen exposure regions tend to have lower property values, while lenders may charge higher interest rates to individuals with increased health risks due to cancer-related conditions, potentially leading to higher medical expenses or reduced income capacity. This study also assesses how carcinogen exposure affects mortgage rates for different racial groups, lender types, and loan purposes. Findings reveal that Black and African American applicants experience a higher mortgage credit premium due to carcinogen exposure, contributing to environmental inequality in the financial market. However, lender types and loan purposes do not significantly alter this relationship.

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# Appendix

| | |
|---|---|
| **1. Variables from Toxic Release Inventory dataset** | |

| Variables name | Sources and description |
|---|---|
| FRS ID | Facility ID made by TRI |
| State, County, FIPS | Geographical Identifiers |
| Latitude, Longitude | Geographical Identifiers |
| Carcinogen | Binary variable, indicating the type of chemical substance observed at a specific data point is carcinogen or not |
| Classification | 3-level variables. Indicates if the chemical is classified as a dioxin or dioxin-like compound, a Persistent Bioaccumulative and Toxic chemical, or a general EPCRA Section 313 chemical.<br>Values: {TRI, PBT, DIOXIN} where:<br>- TRI = General EPCRA Section 313 Chemical<br>- PBT = Persistent Bioaccumulative and Toxic<br>- DIOXIN = Dioxin or Dioxin-like compound |
| Fugitive Air | An estimate of the total quantity of the toxic chemical released as fugitive air emissions at the reporting facility. |
| Stack Air | An estimate of the total quantity of the toxic chemical released as fugitive air emissions at the reporting facility. |
| Total Release | Total onsite release and total offsite release |

## 2. Variables from the HMDA dataset

| Variables name | Descriptions |
|---|---|
| LEI | Lender's Identification |
| Rate Spread | The difference between the covered loan's annual percentage rate (APR) and the average prime offer rate (APOR) for a comparable transaction as of the date the interest rate is set |
| U.S. 30-year Treasury yield spread | The difference between the covered loan's annual percentage rate (APR) and average 30-Year US treasury bond yield of that year |
| Applicant Race | Race of the first applicant or borrower. Aggregated based on the HMDA data:<br>1: White<br>2: Asian<br>3: Black and African American<br>4: Native Americans |
| Applicant Age | Age of the first applicant or borrower:<br>7 age bins, from under 25 to over 74 |
| Loan-to-Value ratio | The ratio of the total amount of debt secured by the property to the value of the property relied on in making the credit decision.<br>Divided into decile bins |
| Property Value Property | The value of the property securing the covered loan or, in the case of an application, proposed to secure the covered loan, relied on in making the credit decision. |
| Income | The gross annual income, in thousands of dollars, relied on in making the credit decision, or if a credit decision was not made, the gross annual income relied on in processing the application.<br>Divided into decile bins |
| Loan Purpose | Purchase a new home or refinance<br>0 for new purchase<br>1 for refinance |
| Regulatory Agency | The integer code corresponding to an institution's regulatory agency<br>1 OCC Office of the Comptroller of the Currency<br>2 FRB Federal Reserve System<br>3 FDIC Federal Deposit Insurance Corporation<br>5 NCUA National Credit Union Administration<br>7 HUD Department of Housing and Urban Development<br>9 CFPB Consumer Financial Protection Bureau |

### 3. Variables from US Census data

*Source: US Census Bureau and U.S Department of Labour, Bureau of Labour Statistics*

| Variables name | Sources and description |
|---|---|
| County Land Area | 2020 land area of the County (square meters) |
| County Housing Density | 2020 housing unit density of the County (square miles) |
| County Unemployment Rate | County's unemployment rate in each year |
| Census Urban/Rural | Define whether a census tract is urban or rural |