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Toxic structures: Speculation and lead exposure in Detroit's single-family rental market

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Abstract

Foreclosure sales permitted investors to purchase large volumes of low-cost residential properties after the last financial crisis, reshaping patterns of property ownership in low-income housing markets across the US. This study links post-foreclosure property acquisitions by investor-landlords to subsequent lead poisoning cases among children under age six living in Detroit, Michigan. We find that the odds of exhibiting elevated blood lead levels (≥ 5 $\mu g/dL$) are higher for children living in investor-owned homes purchased through tax foreclosure sale. These findings highlight the potential for property speculation in post-foreclosure housing markets to exacerbate severe and racialized burdens of excess lead toxicity in low-income communities.

Introduction

The consequences of childhood lead exposure are grave and enduring (Needleman, 2004). Adverse effects of elevated blood lead levels during early childhood include intellectual deficits, neurobehavioral disorders, developmental delays, and lower academic achievement (AAP COEH, 2016). The damages of lead poisoning to the body's major systems are permanent, perpetuating disadvantage across the life course through reduced social, economic, and health outcomes in adolescence and adulthood (Reuben et al., 2017; McDonald and Potter, 1996; Billings and Schnepel, 2018; Zhang et al., 2013; Lanphear et al., 2018). No effective treatments mitigate the irreversible effects of lead toxicity (Dietrich et al., 2004) and public health response is largely restricted to secondary prevention screening programs that remediate lead hazards only after children are poisoned (Lanphear, 2005).

The burdens of childhood lead toxicity in the US are disproportionately borne by Black and low-income populations living in urban areas (White et al., 2016; Oyana and Margai, 2007). This

is a function of segregated housing markets, which constrain residential mobility and restrict low-income residents and people of color to older, lower-quality housing (Lively, 1993; Massey and Tannen, 2015). Cities that were once powerhouses of industrial production are now the principal reservoirs of legacy lead, the majority of which persists in the lead-based paint of homes built before the 1950s that comprise a large proportion of the urban housing stock (Jacobs et al., 2002). In these lead-polluted environments, high and persistent levels of racial segregation make it more likely for low-income Black families to be exposed to housing-based lead hazards, the predominant source of lead exposure for children (Gaitens et al., 2008; Sampson and Winter, 2016; Leech et al., 2016; Moody et al., 2016a,b). The task of maintaining homes in lead-safe condition is an onerous one for low-income owner-occupants who lack the necessary capital and expertise (Campbell et al., 2013); especially vulnerable are the children of low-income tenants, whose safety is largely determined by their landlords' willingness and capacity to control lead hazards (Farr and Dolbeare, 1996).

Excess exposure risks are compounded by a shortage of quality affordable rental housing in many urban areas. This problem is acute in older industrial cities, which maintain high percentages of low-income households and significantly aged housing stocks. While rents in these areas may be low relative to in-demand housing markets, they often consume large and unaffordable fractions of low-income tenants' monthly incomes (Mallach, 2019). Older structures require costly upkeep, but the inability of landlords to ask higher rents in distressed markets induces many to withhold necessary investments (Desmond, 2016). Weak regulations and the high cost of permanent lead abatement mean that owners' lead mitigation strategies, if adopted, are limited to interim controls (e.g., repainting) (NCHH UC, 2004). Landlords facing narrow or negative profits may neglect these and other maintenance and repair needs, or opt to abandon their properties entirely (Desmond and Kimbro, 2015). These conditions help explain why lead-exposure risks are concentrated among children living in older, poorly maintained, single-family homes in the private, low-income rental market (Ahrens et al., 2016; Dewalt et al., 2015; Jain, 2016).

Public health research has long identified landlord behavior as an upstream determinant of childhood lead exposure and a key target for policy intervention in high-risk areas (Korfmacher and

Hanley, 2013). Evidence from several cities suggests patterns of churn and neglect brought by a subset of property owners contributes to toxic disease burdens in low-income urban communities. For instance, a study by Reyes et al. (2006) found that 0.2% of Chicago's building stock housed 2% of all lead-poisoned children between 1997 and 2003. In Jefferson County, Kentucky (home to Louisville) Reissman et al. (2001) found that between 1994 and 1998, just 79 properties accounted for 35% of children with severe ($\geq 20\,\mu g/dL$) lead poisoning. In Rochester, New York, Korfmacher and Kuholski (2007) found that 14% of properties which housed multiple lead-poisoned children between 1993 and 2004 were subsequently abandoned by the owner and transferred to public ownership (usually through tax foreclosure), the majority which were later demolished. These studies invite further inquiry into how patterns of property ownership and disposition in low-income housing markets might shape or reflect the practices of landlords operating in these spaces, with severe implications for health and health equity.

Such questions take on added urgency in light of shifting ownership patterns in low-income urban housing markets, as landlord-investors acquired large numbers of single-family homes in places hit hard by foreclosures (Lambie-Hanson et al., 2019). From the late 1990s to early 2000s, homeowners in urban Black neighborhoods, many in older cities like Chicago, Cleveland, and Detroit, were targeted by predatory lenders offering high-cost and ultimately unsustainable home equity and refinance loans, triggering widespread foreclosure (Immergluck, 2011). Banks subsequently sold a substantial share of repossessed properties in these neighborhoods to large-scale investors, many of them out-of-state operators (Ford et al., 2013; Immergluck and Law, 2014). Investor-landlords in these markets frequently pursue practices intended to maximize short-term profit, including renting properties while withholding maintenance and property taxes and selling homes via high-cost land contracts or rent-to-own arrangements (Author and Author, 2018; Immergluck, 2018). While these practices had never disappeared from the lower-income and typically majority-Black urban neighborhoods targeted by subprime lenders, the foreclosure crisis and its aftermath inaugurated a substantial expansion of predatory ownership activities associated with housing insecurity and negative health outcomes.

Given the constraints of the post-crisis private rental market, a growing number of low-income and credit-impaired households in search of affordable and livable housing have few options other than to contract with landlord-investors (Fields, 2014). Exposure risks may be especially high for tenants renting from investors whose business models rely on bulk acquisition strategies at the bottom of the housing market. Such investors are motivated by aggregate returns, not by the desire to improve individual properties. They therefore make strategic decisions about which properties to keep as long-term speculative holdings, which to quickly sell for profit, which to keep as rentals, and which to simply abandon. When bulk-buying landlords decide to retain homes as rentals, they are more likely to withhold maintenance (including lead abatement) as their acquisitions are typically concentrated in areas with weak demand for housing (Mallach, 2014). Low-income tenants are regularly forced to tolerate unsafe housing conditions, as they can be threatened with eviction if they choose to withhold rent, deduct the cost of needed repairs, or cause a landlord to come under state scrutiny by prompting a lead inspection (Desmond et al., 2013).

Toxic lead exposure may be just one of the potential human costs exacted by opportunistic investments in distressed housing markets destabilized by foreclosures. Foreclosed properties typically experience long periods of vacancy and neglect, all but guaranteeing more hazardous baseline conditions unless the buyer invests significantly in improvements (La Jeunesse, 2013; Li and Walter, 2013). Further, the limited experience and stretched capacity of larger investor-landlords may negatively affect rehab and maintenance behaviors, resulting in poorer housing quality. The incentive to guarantee cash flow through reduced maintenance costs increases the risk of lead exposure. Most likely to suffer these dangerous and unfit living conditions are low-income tenants whose eviction and credit histories render them the most marginal in the housing market—positions disproportionately occupied by Black families with young children (Desmond et al., 2013). When investors abandon properties at the end of their productive life, their deterioration and eventual demolition introduces lead-containing dust into the nearby residential environment that can be tracked indoors or absorbed by children during outdoor play, passing on risks to the entire community (Farfel et al., 2003, 2005; Rabito et al., 2007).

This article examines the relationship between investor-ownership in foreclosed homes and the risk of childhood lead exposure in low-income housing markets. We do so by linking post-foreclosure property acquisitions by investor-landlords to subsequent lead poisoning cases among children under age six in Detroit, Michigan, a predominantly Black and low-income city with a heavily lead-polluted residential environment and distressed housing market. We posit that the business models of investor-landlords who purchase foreclosed properties make these actors less likely than other owners to maintain their acquisitions and undertake lead remediation actions. Therefore, we hypothesize that children living in renter-occupied homes purchased by investors through foreclosure auction will be more likely to exhibit elevated blood lead levels (EBLL $\geq$ 5 $\mu g/dL$), net a range of conditions at the individual, property, and neighborhood levels associated with risk for EBLL in past research. We anticipate that the risk associated with investor ownership will further contribute to the risks posed by renter-occupancy (compared with owner-occupancy) and by proximity to nearby property abandonment and demolition activity, which have been documented in previous research. These findings lend new insight on how the rise in predatory and speculative landlord activity in the aftermath of the foreclosure crisis might present unprecedented social and physiological harms that can further erode the health of vulnerable households and communities.

Study Setting

Housing and Health Context

Several elements of Detroit's socio-historical context and current political economy precondition our hypotheses and make Detroit an appropriate setting to investigate the potential for post-foreclosure investment activity to exacerbate unequal burdens of childhood lead poisoning. As the center of one of the most segregated metropolitan areas in the US, Detroit maintains a high level of racialized poverty that disproportionately impacts young children (Logan and Stults, 2011). Between 2013 and 2017 Detroit's population of nearly 680,000 was 85% Black, making it the largest majority-Black US city (US Census Bureau, 2017a). Detroit had the highest rate of childhood poverty among large and mid-sized US cities, with 60% of children under age six living below the

federal poverty line, 75% of whom lived in renter households (Ruggles et al., 2019).

Due to the timing of Detroit's industrial rise, the city's housing is predominantly older, detached single-family residential. Table 1 shows that 86% of children under age six live in single-family housing, either attached or detached. Absent large-scale remediation investments, the advanced age of this housing stock qualifies Detroit as one of the most lead-polluted residential environments of any major US city (US Census Bureau, 2017a). As shown in Table 2, a full 90% of Detroit children under age six reside in housing built in 1979 or earlier (the federal government banned residential lead-based paint in 1978), with 57% living in housing built before 1950 when lead concentrations in paint were significantly higher (Clark et al., 1985). These percentages are even higher for children in renter households in single-family detached housing, with 87% living in homes built before 1960.

Decades of deep disinvestment and credit starvation mean that much of the housing available to low-income families is in substandard condition (Wayne Metropolitan Community Action Agency, 2019). In 2017, 13% of Detroit metropolitan area renters with annual incomes less than $20,000 lived in housing which the Department of Housing and Urban Development (HUD) qualified as inadequate (US Census Bureau, 2017b).[1] Quality housing is also increasingly hard to come by, as the number of adequate and affordable rental units available to extremely low-income renters (households with incomes at or below 30% of the area median) in Detroit's Wayne County fell from about 48,000 (54 units per 100 renters) to 24,500 (25 units per 100 renters) between 2000 and 2013 (Leopold et al., 2015).

Hence, Detroit's segregated low-income housing market is a universe of limited choice, replete with toxic structures that threaten the health and well-being of families. One consequence of these structures is a staggeringly high burden of excess lead toxicity among Detroit children. In 2016, 8.8% of children under the age of six in Detroit who were screened for lead exhibited EBLL (≥ 5 $\mu g/dL$), accounting for 36% of EBLL cases statewide (Detroit is home to just 8.5% of Michigan's

[1]The American Housing Survey (AHS) classifies occupied housing as moderately or severely inadequate based on a set of criteria relating to the property's physical conditions (e.g., plumbing, heating, electrical) (Eggers and Moumen, 2013). As the AHS sampling frame encompasses Detroit's more affluent suburbs (which contain newer housing stocks), this estimate likely understates the prevalence of poor housing quality in Detroit.

Table 1: Children under age six by units in structure, Detroit, 2013–2017

Units in structure	n	pct.	cum. pct.
1-family house, detached	44,334	77.8	77.8
1-family house, attached	4,748	8.3	86.1
2-family building	2,896	5.1	91.2
3-4 family building	946	1.7	92.8
5-9 family building	1,250	2.2	95.0
10-19 family building	847	1.5	96.5
20-49 family building	972	1.7	98.2
50+ family building	1,019	1.8	100.0

Source: American Community Survey 2017 5-year estimates Public Use Microdata Sample (PUMS) (Ruggles et al., 2019).

Note: Includes children living in Public Use Microdata Areas (PUMAs) where the majority of respondents live in the city of Detroit. Excludes children living in mobile homes or trailers. All values are derived from person-weighted observations.

Table 2: Children under age six by age of structure, Detroit, 2013–2017

Year built	n	pct.	cum. pct.
1939 or earlier	18,768	32.9	32.9
1940–1949	13,878	24.3	57.3
1950–1959	13,157	23.1	80.3
1960–1969	3,566	6.3	86.6
1970–1979	2,152	3.8	90.4
1980–1989	1,066	1.9	92.2
1990–1999	1,551	2.7	95.0
2000–2009	2,713	4.8	99.7
2010–2016	161	0.3	100.0

Source: American Community Survey 2017 5-year estimates Public Use Microdata Sample (PUMS) (Ruggles et al., 2019).

Note: Includes children living in PUMAs where the majority of respondents live in the city of Detroit. Excludes children living in mobile homes or trailers. All values are derived from person-weighted observations.

children under age six); during the same time period, the average percentage of EBLL in Michigan was 3.6% (Michigan CLPPP, 2017a).[2] Of the 17 Michigan ZIP codes in 2016 where more than 10% of all tested children demonstrated EBLLs, 10 were in Detroit; in one ZIP code, more than one in five (22%) children experienced toxic levels of lead contamination, the highest in the state (Michigan CLPPP, 2017b).

Prior literature positions the excess burden of childhood lead exposure and its consequences in Detroit within a broader context of environmental racism that manifests in metropolitan areas across the US (Sampson and Winter, 2016; Morello-Frosch and Lopez, 2006; Pulido, 2000). Residents of Detroit's predominantly Black and low-income neighborhoods suffer disproportionately and cumulatively from both exposure to an array of environmental health hazards and vulnerability to poor health (Schulz et al., 2016; Gee and Payne-Sturges, 2004; Moody and Grady, 2017). Recent research by Moody et al. (2016a,b) found that wide racial disparities in childhood lead poisoning in the Detroit metropolitan area could be mostly attributed to the concentration of Black children within neighborhoods characterized by very low and low socioeconomic position (SEP) (mostly in the city of Detroit) and the overrepresentation of White children in middle, high, and very high SEP neighborhoods in the suburbs. Investigating the effects of early childhood lead exposure on long-term academic achievement among public school children in Detroit, Zhang et al. (2013) found that children who demonstrated blood lead levels $\geq 10\ \mu\mathrm{g/dL}$ before the age of six were more than twice as likely to score poorly on academic achievement tests in the third, fifth, and eighth grades compared to children who did not demonstrate elevated blood lead exposure ($\leq 1\ \mu\mathrm{g/dL}$).

Foreclosure and Speculation

Moreover, patterns of property ownership in Detroit, a city once renowned for its high level of Black homeownership, shifted dramatically over the past decade as successive waves of mortgage

[2]Differences in the completeness and representativeness of blood lead surveillance data exist between Detroit and the state as a whole, precluding accurate comparisons between their respective EBLL proportions. Michigan's screening programs are designed to target children in high-risk groups (e.g., Medicaid recipients) and areas (e.g., Detroit and other cities with old housing stocks). In 2016, 40% of Detroit children under age six were tested for lead, compared to 23% of children statewide.

and tax foreclosures dispossessed thousands of low- and middle-income households of their homes, contributing to Detroit's transition in 2010 from a majority-owner to a majority-renter city (Author and Author, 2018). Predatory lenders targeted Detroit homeowners and homebuyers, leading to a large number of mortgage foreclosures. The ensuing recession exacerbated secular trends in poverty and unemployment, leading to further delinquencies and foreclosure (Ashton, 2010; Wyly et al., 2009). Between 2005 and 2013 there were more than 70,000 completed mortgage foreclosures in Detroit, involving nearly 30% of the city's residential properties (CoreLogic, 2014; Data Driven Detroit, 2010).

In the context of plummeting home values, inflated property tax assessments, and growing financial stress, Detroit experienced a second wave of foreclosures stemming from unpaid property taxes (Atuahene and Hodge, 2017; Dewar et al., 2015). Mortgage foreclosures and the recession caused home values in Detroit to drop by about 80%, but Detroit's tax assessor did not complete a citywide reassessment until 2017, resulting in inflated tax bills that overtaxed Detroit homeowners by at least $600 million (Deng et al., 2018; MacDonald and Betancourt, 2020). Under Michigan law, a tax delinquent property is foreclosed after the third year of non-payment (Michigan Public Act 123 of 1999). Since 2002, Wayne County, the foreclosing unit of government for the City of Detroit, has held an annual auction for the sale of foreclosed properties in September for the price of outstanding taxes (plus interest and fees); any properties that go unsold are offered at a second auction in October, for a starting price of just $500. Detroit properties that remain unsold are typically transferred to city ownership for management, sale, or demolition. Between 2002 and 2016, roughly 110,000 Detroit homes entered the Wayne County tax foreclosure auction, with approximately 90% of foreclosures taking place since 2010 (City of Detroit Office of the Assessor, 2014; Wayne County Treasurer, 2016). Between 2010 and 2017, more than 47,000 properties with occupied structures entered the foreclosure auction, including more than 15,700 owner-occupied homes in the span of three years between 2014 and 2016 (Wayne County Treasurer, 2016; City of Detroit, 2018).

Over the past decade, foreclosure auctions in Detroit have functioned largely as pipelines for

investors to acquire properties at deeply discounted prices, often in large volume. As speculative bulk buying follows supply, the annual tax auction has served as the primary instrument for this type of purchasing since 2010 when mortgage foreclosures began to dwindle (Author and Author, 2018). Researchers document how speculators and slum-landlords have utilized the tax auction to accumulate inventories of low-value housing, mostly by way of the second auction (Author, 2013; Dewar et al., 2015). Between 2005 and 2015, investors accounted for 88% of tax auction sales, with most (68%) going to large- and medium-scale investors (40% to buyers who purchased 50 or more houses, and 28% to buyers who purchased 10-49 houses, respectively) (Author and Author, 2018).

Evidence from Detroit lends insight on the harmful consequences of these acquisition patterns for the health and stability of low-income families, as speculators turn profits by cycling tenants through houses in dangerous condition. Author and Author (2019a) found that nearly a quarter of tax foreclosure sales between 2005 and 2015 were linked to one or more subsequent eviction filings, with large investors more likely to file repeat evictions on individual properties. Among homes purchased by the top 20 tax auction buyers and linked to an eviction, 60% experienced a minimum of two filings. Investigative reports reveal how investors often use eviction as means to pressure tenants for payment on substandard properties (MacDonald, 2017a), where lead hazards can easily exist alongside other unsafe conditions like mold, pests, faulty electrical, lack of heat, and sewage backups (MacDonald, 2017b,c). Lack of enforcement of the city's rental regulations (which require lead inspections and clearance prior to rental registration for homes built prior to 1978) contributes to this precarity, as just 3% of Detroit's rental units were registered with the city as of 2016 (MacDonald, 2017d). Despite a recent initiative by the City of Detroit to increase rental code compliance, enforcement of local lead-poisoning prevention laws has been lax, and especially inadequate in ZIP codes where lead exposure rates are highest (MacDonald, 2018).

Research also implies a connection between speculation and demolition activity in Detroit that increases public costs and extends lead exposure risks onto children who live nearby investors' discarded properties. In response to the city's growing inventory of abandoned properties, Detroit's

mayor launched an aggressive demolition program in 2014 which has since razed more than 19,000 residential structures (City of Detroit, 2019). Linking public demolition data to prior chains of ownership, Author and Author (2019b) observe a relationship between investor involvement in the Wayne County tax foreclosure auction and likelihood of subsequent demolition outcomes, and find that houses purchased by large investors out of tax foreclosure are nearly twice as likely to be later demolished than those owned by small landlords. Analyzing blood lead tests for children under age six between 2014 and 2016, the Detroit Health Department (2017) demonstrated an association between demolition activity within 400 feet of a child's home and likelihood of EBLL in a subsequent blood lead test during the summer months, finding evidence for a dose-response relationship between demolitions and EBLL that increased with proximity in both space and time.

Thus, young children in Detroit increasingly reside in or near lead-contaminated rental housing owned by investor-landlords whose business models are organized around acquiring distressed housing, withholding maintenance to maximize profits, and abandoning properties rendered uninhabitable. These conditions threaten to exacerbate what is already an immense burden of lead toxicity among Detroit children. This study examines whether the growing role of speculation in Detroit's low-income housing market corresponds with higher risks for resident children, with broad implications for health inequity.

To test the relationship between post-foreclosure property acquisition and childhood lead poisoning in Detroit, we linked records of venous blood tests reported to the Michigan Childhood Lead Poisoning Prevention Program (MCLPPP) between 2014 and 2017 to a variety of property- and neighborhood-levle characteristics.[3] We restricted our sample to children under six years of

[3]Blood lead testing data were provided the Detroit Health Department (DHD). DHD excluded capillary (finger prick) tests on the basis that they can produce false positive results and, if elevated, must be confirmed with a venous blood test. Michigan has mandatory reporting for all blood lead test results, but blood lead testing is not universal. Michigan law requires that all Medicaid-enrolled children be tested for lead exposure at 12 and 24 months of age, or once between 36 and 72 months of age if not previously tested, although significant testing gaps remain (33.3% of Medicaid-enrolled children under age six were tested in 2016). The MCLPPP reports that between 2014 and 2016 an average of 38.5% of Detroit children under the age of six were tested. While MCLPPP does not report testing rates by Medicaid enrollment for Detroit, most children in the study sample were likely enrolled in Medicaid, as Medicaid-enrolled children accounted for an average of 76.1% of tested children under age six in Wayne County in 2015 and 2016, and an average of 70.8% in the state of Michigan between 2014 and 2016 (MCLPPP did not report testing rates by Medicaid enrollment at the county level in 2014).

age, the population most susceptible to the long-term negative effects of lead exposure (Bearer, 1995; Lidsky and Schneider, 2003). We classified observed blood lead levels into a binary variable distinguishing between values of at least 5 $\mu g/dL$ (EBLL) and all lower values. To remove duplicate records for individual children, we restricted the blood test data to the earliest testing date after grouping observations by property parcel number, age in years, and sex.

Our central independent variable of interest, investor-ownership through tax-auction acquisition, is derived from property sale records of the annual Wayne County tax foreclosure auctions held between 2005 and 2016.[4] Using these auction sales records, we coded buyers as investors based on the presence of corporate identifiers in their names (e.g., "LLC") or, regardless of presence of corporate identifier, the same name was used to purchase two or more properties, excluding names associated with government and nonprofit entities. To establish temporal order between the property's acquisition through tax sale and the child's subsequent blood lead level, we selected the most recent sale prior to the specimen collection date for properties with multiple auction events.

As lead exposure risk and investor ownership are closely linked to housing tenure, we also classified the properties in which children reside as likely renter-occupied based on the combination of tax assessor files from the City of Detroit and real estate transaction records obtained from CoreLogic. For each year of assessor's data from 2014 to 2017, we obtained the property address, owner's name, tax address (where the tax bill is mailed), and the last sale date. Given the lag between property transactions and when ownership information is updated in the tax assessor database, we checked each property listed in the assessor's file for later transactions in the CoreLogic. When we found sales in the CoreLogic data file dated after than the last sale date in the assessor's file, but no later than the end of the individual year being coded for tenure, we updated owner and tax address information using the most recent sale. We then coded properties as owned by investors when the tax address did not match the property address or where the owner name matched a corporate identified. In cases where there was disagreement between tax auction investment prior to test data

[4]We obtained records of auction-related property transfers from the Wayne County Treasurer to third-party buyers for 2005 to 2015, and supplemented these with 2016 tax auction results tracked by Loveland Technologies, a private data vendor with direct access to online auction bidding activities.

and ownership in the current year based on the procedure just described, we updated the investor owner category to reflect past tax auction investment. In other words, all cases in our sample where children are coded as living in tax auction investor owned properties are also coded as living in rental properties.

As exposure to recent demolitions is associated with EBLL, we include a variable indicating demolitions occurring near a child's home by drawing on records of demolitions completed in Detroit from 2014 to spring 2019. For tests occurring on or after March 1, 2014, we counted the number of demolitions occurring within 400 feet of the property in which the child resided and up to 45 days prior to the specimen collection. The 400-foot radius approximates the dispersion zone for lead dust from a demolition assuming dust suppression techniques like wetting (Jacobs et al., 2013), while the 45-day period reflects the half-life of lead in the blood (Rabinowitz et al., 1976). As proximity to vacant old housing is also associated with increased risk of lead exposure (Castro et al., 2019; Bailey et al., 1998), we proxied nearby vacancy by including a count of properties located within 200 feet of a child's residence that were demolished up to 365 days after the date of testing. We classified the number of both past and future demolitions associated with each parcel into three levels: 0 demolitions, 1 demolition, and 2 or more demolitions.

To control for property characteristics, we joined each year of blood test data to our updated property tax assessor data corresponding to the same year. From these data we retrieved the year the property was built, assessed value, and property class (e.g., commercial, residential). We retained only observations for children living in units located on parcels with improved residential properties, almost the entirety of which are single-family homes.[5] We dropped all observations we were unable to join to assessor data or from which we were unable to obtain the year the housing unit was built. We accounted for higher levels of home-based lead paint by including dichotomous variable indicating whether the unit was built before 1950. To control for assessed value, we used the State Equalized Value (SEV) from the year of the blood test. SEV is based on 50% of market value as

[5]Detroit assessor data only contains information on the property class of a given parcel, not the number of units. By including only improved residential properties, we exclude all cases for children living in multifamily properties.

required by state law.

We further adjusted our models for individual and neighborhood covariates related to BLLs in children. We included the child's sex as a dummy variable, with female as the reference category. We included a categorical control variable of age (in years) at the time of testing. In addition to controlling for year of test, we accounted for seasonal variation in blood lead concentrations (Levin et al., 2008) by including a dummy variable indicating whether the test occurred between May and September. As socioeconomic data on the child's family is not available, we employed census tract-level poverty and tenure as a spatial proxy for socioeconomic position (Moody et al., 2016b; Krieger et al., 2003). We also included census tract-level housing vacancy rate and the percentage of housing units built before 1940 to account for regional variation not accounted for by our use of future demolitions as indicators of nearby vacant homes. Lastly, we controlled for unobserved variation between spatial units in environmental lead exposure with ZIP code fixed effects, which restricts our analysis to variation within groups. We dropped cases contained in tracts with fewer than five total cases and cases contained in ZIP codes lacking at least one case in each level our our categorical variable for nearby past demolition.

Using these data we estimate four logistic regression models, taking the binary outcome of EBLL as our dependent variable. The first two models are run using our full sample, generated as described above. In terms of property ownership, Model (1) includes only our tax auction investor variable. Model (2) adjusts this relationship by additionally controlling for tenure (i.e., rented vs owned). Models (3) and (4) account for potential selection bias in our estimation of the effect of tax auction investor ownership and EBLL. Although we control for a variety of property- and neighborhood-level characteristics, unobserved differences in property characteristics may both select properties into our treatment group (i.e., tax auction investor ownership) and increase the odds of EBLL. To account for this potential bias, we reduced our sample to cases where (1) the property was either purchased at auction in the past or (2) will be placed at auction in the future. Drawing on records of properties eligible for tax auction in each year between 2014 and 2017 and records of properties at risk of tax foreclosure in April 2018 (indicating three consecutive years of tax delin-

quency) scraped from the website of Loveland Technologies, we checked all records in our test sample for inclusion in any of these records. In Models (3) and (4) we therefore compare properties purchased at auction by investors against properties facing risk of tax foreclosure. This is a highly conservative comparison group given that the logic of the tax auction is based on the assumption of reinvestment and improved conditions following sales, while tax delinquency and foreclosure are associated with disinvestment and deterioration.

Results

Table 3 presents descriptive statistics of our sample, which includes 37,833 total blood lead observations for children younger than age six living in residential properties for which sufficient property-level data were available. The vast majority (84%) of children in our sample live in housing built before 1950, with children exhibiting EBLL even more likely to live in older housing at 93%. Children in the sample lived in neighborhoods with generally high rates of poverty (nearly 40% for all children) that were on average 77% Black, closely corresponding to the city's characteristics as a whole. The overall average SEV of roughly $10,600 (approximating a market value of less than $21,200) is rather low. On average, children in the full sample lived in neighborhoods where 29% of all housing units were vacant, with children exhibiting EBLL tending to live in tracts with higher levels of vacancy. Lastly, the investor owner variable shows an association between renter-occupancy and EBLL, with 64% of children exhibiting EBLL likely living in rental housing compared to 61% among those without EBLL. Tests of independence calculated for these selected covariates based on EBLL status were highly statistically significant with the exception of tract-level percent Black. These covariate levels and between-group comparisons reflect segregation patterns concentrating Black residents and environmental health hazards within the city of Detroit (Darden et al., 2010; Schulz et al., 2016). While racial differences between children exhibiting EBLL are evident in data drawn across the metropolitan area (Moody et al., 2016b), they are limited within the city itself due to the prominence of neighborhood socioeconomic disadvantage (Moody et al., 2016a). Thus we do not include racial composition as a covariate in our models.

Table 3: Sample data descriptive statistics

	All		EBLL = No		EBLL = Yes		
Variable	mean	std	mean	std	mean	std	p
Male	0.51	0.50	0.51	0.50	0.56	0.50	***
Month of test: May–Sept	0.50	0.50	0.50	0.50	0.58	0.49	***
Built before 1950	0.84	0.37	0.83	0.37	0.93	0.25	***
SEV	10.62	4.46	10.65	4.42	10.26	4.78	***
Tax auction investor	0.17	0.37	0.16	0.37	0.19	0.40	***
Investor owner	0.61	0.49	0.61	0.49	0.64	0.48	***
Future tax foreclosure	0.35	0.48	0.35	0.48	0.42	0.49	***
Tract % vacant housing units	29.22	11.64	28.82	11.45	33.82	12.74	***
Tract % homes built before 1940	34.47	22.18	33.74	22.10	42.83	21.44	***
Tract % below poverty	38.40	10.64	38.28	10.61	39.78	10.87	***
Tract % renter households	46.93	11.48	46.82	11.42	48.30	12.07	***
Tract % Black alone	77.26	31.79	77.24	31.83	77.52	31.29	0.634
Observations	37,833 (1.00)		34,829 (0.92)		3,004 (0.08)		

Notes: Tests of independence between groups split on dichotomous EBLL variable based on t-tests (continuous variables) and χ^2 tests (binary variables); *p<0.05; **p<0.01; ***p<0.001.

Table 4 shows the association between our categorical variables for recent nearby demolitions and EBLL. These descriptive observations reflect previous findings from Detroit which suggest a dose-response relationship between spatial proximity to nearby demolitions and risk of EBLL (Detroit Health Department, 2017). Roughly 13% of children living in houses near two or more recent demolitions exhibit EBLL compared to less than 8% of children not living near any recent demolitions. These results are similar for future demolitions, which we use to proxy for nearby vacant properties at the time of blood testing, with each increasing level of the demolition category associated with higher odds of EBLL.

Table 5 shows the results of our regression analyses exploring the relationship between investor-ownership in foreclosed homes and the risk of childhood lead exposure among Detroit's majority-Black and predominantly low-income youth. Model (1) is based on our full sample of children living in both renter- and owner-occupied properties. Consistent with prior research, we find: sex is associated with EBLL, with male children having higher odds of exhibiting EBLL than female children; seasonality is important, with tests conducting in warmer months (when children are ac-

Table 4: Elevated blood lead status by nearby demolitions

	Number of nearby past demolitions							
	0		1		2+		All	
EBLL	n	%	n	%	n	%	n	%
No	32,673	92.2	1,562	90.7	594	87.4	34,829	92.1
Yes	2,758	7.8	160	9.3	86	12.6	3,004	7.9
All	35,431	100.0	1,722	100.0	680	100.0	37,833	100.0
	Number of nearby future demolitions							
	0		1		2+		All	
EBLL	n	%	n	%	n	%	n	%
No	30,311	92.3	3,446	91.2	1,072	88.6	34,829	92.1
Yes	2,533	7.7	333	8.8	138	11.4	3,004	7.9
All	32,844	100.0	3,779	100.0	1,210	100.0	37,833	100.0

Notes: χ^2 tests of independence for both past and future demolition categories and EBLL variable significant with p-value < 0.001. Past demolition variable calculated including demolitions occurring within 45 days prior and 400 feet from test property. Future demolition variable calculated including demolitions occurring within 200 feet from test property and up to 365 days after test date.

tive outside) having higher odds of showing EBLL; and home age has a strong association with EBLL, with odds of EBLL for children living in a home built before 1950 more than 80% higher than other children. Home value has a negative association with EBLL, similarly reflecting the relationship between property conditions and blood lead levels. Location near a single recent or future demolition is not significantly associated with higher odds of EBLL, but larger numbers (2+) of both past and future nearby demolitions are positively associated with the odds of exhibiting EBLL, also consistent with past research (Rabito et al., 2007). In terms of neighborhood-level covariates, both the housing vacancy rate and the percentage of homes built before 1940 have positive relationships with EBLL, indicating the persistence of an association between neighborhood-level vacancy and blood lead levels at a scale wider than 200 feet, as well as the significance of proximity to older homes beyond the child's own residence. Neither of the two tract-level covariates indexing socioeconomic characteristics is significant, which likely reflects our use of fixed effects to constrain analysis to variation within but not between ZIP codes. Lastly, our results show a positive relationship between tax auction investor ownership and EBLL, with the odds of EBLL for

children living in properties owned by these investors, on average, being roughly 50% higher than for children living in other properties.

Models (3) and (4) are our most conservative models and they are estimated using a sample restricted just to tests linked to properties either currently owned by tax auction investors or potentially subject to tax foreclosure in the near future, regardless of current ownership. The results for our main confounding variables remain largely the same, although both categories of prior demolitions are significant and have larger coefficients. Model (3) shows that the odds of a child living in tax auction investor owned property remain higher (p<0.001), even when compared strictly to test results for children living in homes eligible for tax foreclosure in the near future. Model (4) shows that this relationship persists even after adjusting for tenure, although with slightly lower statistical significance (p<0.05).

Conclusions

Poor and unaffordable housing conditions are increasingly consistent threats for those seeking shelter in low-income housing markets, leaving families with little option but to choose between toxic structures. In Detroit and other segregated cities with old and deteriorating housing stocks, these structures can be particularly dangerous for young children of color who are most susceptible to the irreparable effects of lead toxicity on their developing brains and bodies. A growing area of research reveals that structural changes to low-income markets after the last financial crisis—including high rates of foreclosure, rental market tightening, and the rise of bulk-ownership by landlord-investors—propagate harms that threaten the health and stability of low-income and disproportionately Black families. Evident in the wake of these changes, particularly in distressed markets, is an observed property lifecycle defined by foreclosure, speculation, eviction, and demolition. This study situates the increased risk of childhood lead exposure within this cycle to begin to understand the implications of these patterns for public health and health equity.

Our findings from Detroit indicate that young children who live in rental properties owned by investor-landlords active in the annual tax foreclosure auction are more likely than children in other

Table 5: Logistic regression results for elevated blood lead levels

	(1)	(2)	(3)	(4)
Sex: Male	1.244***	1.246***	1.226***	1.227***
	(0.041)	(0.041)	(0.055)	(0.055)
Month of test: May–Sept.	1.427***	1.427***	1.442***	1.442***
	(0.041)	(0.042)	(0.058)	(0.058)
Home built before 1950	1.854***	1.854***	1.884***	1.884***
	(0.082)	(0.082)	(0.116)	(0.115)
ln(SEV)	0.825***	0.816***	0.703***	0.699***
	(0.057)	(0.057)	(0.080)	(0.080)
Prior demos: 1	1.137	1.131	1.382**	1.376**
	(0.095)	(0.095)	(0.127)	(0.127)
Prior demos: 2+	1.389**	1.391**	1.458**	1.468**
	(0.138)	(0.138)	(0.158)	(0.159)
Future demos: 1	1.030	1.027	0.973	0.971
	(0.065)	(0.065)	(0.101)	(0.101)
Future demos: 2+	1.239**	1.231**	1.322*	1.320*
	(0.098)	(0.098)	(0.140)	(0.140)
Tract % vacant housing units	1.012***	1.012***	1.004	1.004
	(0.003)	(0.003)	(0.003)	(0.003)
Tract % homes built before 1940	1.014***	1.014***	1.018***	1.018***
	(0.002)	(0.002)	(0.003)	(0.003)
Tract % below poverty	0.999	0.999	0.998	0.998
	(0.003)	(0.003)	(0.004)	(0.004)
Tract % renter households	1.002	1.001	0.999	0.999
	(0.002)	(0.002)	(0.003)	(0.003)
Tax auction investor	1.495***	1.393***	1.265***	1.183**
	(0.058)	(0.064)	(0.063)	(0.072)
Investor owner		1.176***		1.160
		(0.051)		(0.077)
Constant	0.018***	0.017***	0.039***	0.037***
	(0.350)	(0.350)	(0.468)	(0.475)
Age in years FE	Yes	Yes	Yes	Yes
Year of test FE	Yes	Yes	Yes	Yes
ZIP code FE	Yes	Yes	Yes	Yes
Observations	37,833	37,833	16,566	16,566
Log Likelihood	-9,690.466	-9,683.811	-4,706.673	-4,704.487
McFadden pseudo R^2	0.076	0.077	0.084	0.084

Notes: *p<0.1; **p<0.05; ***p<0.01

Shows exponentiated coefficients and robust standard errors clustered by census tract (in parentheses).

living arrangements to exhibit EBLLs, net a range of property- and neighborhood-level covariates. These findings are largely consistent with our study hypothesis, and indicate a connection between post-crisis patterns of property investment and adverse health outcomes that is not simply a function of tenure status, housing age, or neighborhood characteristics. Our analysis cannot determine the mechanisms underlying this relationship, such as whether these results might reflect a tendency for foreclosed properties to be in poorer condition, or a greater likelihood of auction-buyers to neglect the maintenance and repair needs of their occupied properties. Still, this evidence suggests that the business models and practices of property speculators operating in low-income rental markets threaten to further elevate the risk of lead poisoning among marginally housed children.

Additionally, and consistent with prior analyses, we observe that risk for EBLL is also higher for children who live in the vicinity of two or more houses that are vacant or demolished. However, we find the relationship between EBLL and proximity to publicly funded demolitions does not hold when we restrict our analysis to renter-occupied properties. This inconsistency may be due in part to more pervasive disinvestment in renter-occupied properties and neighborhoods. For instance, the lower prevalence of nearby demolitions in the renter sample may be attributed to the city government's effort to concentrate blight removal in a subset of strategic neighborhoods which it has targeted for redevelopment, and which tend to have lower proportions of renter-occupied households (Detroit Land Bank Authority, 2013). Our study does not offer evidence specific to vacancy and demolitions caused directly or solely by investors. Still, these findings build on previous research from Detroit during the same time period which documents a direct connection between post-foreclosure investor-ownership and subsequent demolition outcomes (Author and Author, 2019b). Considered collectively, this evidence suggests that the lead exposure risks posed by speculation extend beyond those incurred to children living inside investor-owned properties, to those that live near their properties when they are abandoned or demolished due to neglect.

Our findings should be considered in light of several limitations. Although we include a wide range of multilevel covariates, unobserved heterogeneity may nonetheless influence our results. For instance, we were unable to fully consider variation in lead exposure risks posed by other known

environmental sources of lead within and outside the home, such as lead leached into drinking water, released into the air as emissions, and deposited in soils (Mielke and Reagan, 1998; Hanna-Attisha et al., 2016; Laidlaw and Filippelli, 2008). Housing age is not only a surrogate for the presence of leaded paint, but also lead service mains and fixtures (Troesken and Beeson, 2003); while our use of housing age as a covariate at the property and neighborhood levels helps to mitigate potential bias stemming from this exposure pathway, the presence of lead service lines has been found to be a risk factor for EBLL independent of housing age (Brown et al., 2011). The disproportionate proximity of low-income Black communities in Detroit to polluting facilities and heavy commercial traffic contributes to high burdens of airborne and depositional lead emissions (Moody and Grady, 2017; Downey, 2006; Wu and Batterman, 2006). Urban surface soils are concentrated repositories of legacy lead from gasoline exhaust and past and present industrial activity (Filippelli and Laidlaw, 2010), and re-suspension of lead contaminated soils has been shown to influence the distribution of childhood lead toxicity in metropolitan Detroit (Zahran et al., 2013). While we presume based on prior evidence that the primary mechanism for lead exposure is deteriorating lead-based paint in and around children's homes, we do not test these pathways directly.

Further, the universe of blood lead observations used for this analysis is not representative of all Detroit children. To focus blood lead surveillance on children who are at the greatest risk for lead poisoning, the state requires blood lead testing only for Medicaid-enrolled children (Michigan CLPPP, 2017a). Thus, we cannot eliminate the possibility of selection bias stemming from the sample's likely over-representation of children from low-income families and under-representation of uninsured children. Lastly, while blood lead measurements provide the most reliable available estimate of recent exposures, blood-lead elimination times vary with age and exposure history (ATSDR, 2007). In children, chronic lead exposure from both internal (e.g., bone) and external sources can cause blood lead levels to remain elevated for several months to more than a year (Manton et al., 2000; Dignam et al., 2008). While an average of two years between investor-acquisition and testing lessens this concern, it is possible that in some cases EBLL could have preceded residence in a speculator-owned house.

Further research is necessary to determine the extent to which our findings are applicable to other urban contexts. The Wayne County tax auction after the last financial crisis was unprecedented in terms of its volume and the opportunities it generated for speculative bulk buyers. We expect that the actors, practices, and outcomes we observe would differ in less distressed housing markets with newer or less deteriorated housing stocks. Yet the harmful connection between investor-acquisition through foreclosure pipelines and the health threats posed to vulnerable tenants is likely not unique to Detroit, and instead reflective of a set of structural conditions and processes common to low-income housing markets in urban settings which continue to bear the brunt of racialized poverty and disinvestment.

Our results contribute to a growing body of evidence which indicates the problematic nature of property speculation, particularly through foreclosure markets, by documenting a clear association between bulk investor-ownership and negative health outcomes for Detroit's low-income Black children—the majority of the city's youth. Given that children who live in segregated, low-income housing markets already bear a disparately high level of toxic disease burden, our results suggest that the growing role of speculators in these places is a threat which can perpetuate and even exacerbate stark racial and spatial inequities in childhood lead poisoning. These findings have widespread implications for population health given that residential segregation preconditions re-emergent cycles of predatory property relations and persistent, intersectional health inequities along the axes of race, class, and geography. The myriad consequences of lead poisoning for the long-term health, well-being, and life opportunities of affected children and families of color mean that these toxic structures are likely to reproduce, transmitting social, economic, and embodied disadvantages within and across generations.

As toxic structures are produced, they may be deconstructed. The relationships and risk identified in this analysis are situated within a private housing market that is structured through a public process of repossession, disposition, and demolition. By focusing on this housing lifecycle we can identify critical intervention points for public agencies to limit potential lead exposure. These opportunities exist because many of these houses pass through public ownership prior to investor

ownership, are operated as rental units falling under a city ordinance directly addressing lead and habitability, or their demolition is funded and overseen by a public agency.

Tax auctions continue to dispossess Detroit residents and serve as the city's primary pipeline for bulk buyers to acquire properties. Policies and programs which proscribe the sale of owner-occupied homes and offer tenants the right of first-purchase may stem displacement and narrow this foreclosure pipeline, while enforcement of existing auction participation requirements that prohibit tax delinquency and code violations on previous purchases could restrict access by unscrupulous investors. Given that foreclosed properties are at higher risk for deterioration, closing the"disclosure loophole" (which exempts foreclosure sales from federal obligations to convey known lead hazards to future renters or buyers) and enhancing disclosure rules to require inspection at time of sale can improve awareness of lead hazards among owners and occupants (Korfmacher and Hanley, 2013, pg. 808). Efforts to increase and monitor compliance with Detroit's rental code and rigorous lead safety requirements are urgently needed, and our findings suggest that targeted enforcement among rental properties purchased by landlords through tax foreclosure sale is likely to be an effective strategy for limiting childhood lead exposure. Finally, implementation and oversight of demolition protections involving notification, education, and relocation for residents, and training, monitoring, and enforcement of lead-safety protocols for contractors, are necessary to mitigate the potential harms of high-volume demolition (City of Detroit Health Department Task Force on Demolitions and Health, 2017). These public policies have material consequences that disproportionately impact the health and life outcomes low-income and vulnerable populations, positioning public officials to intervene effectively and immediately.

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