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Abstract

How do credit-constrained communities cope with the financial consequences of environmental crises? Beginning in April 2014, the residents of Flint, Michigan, were exposed to lead-contaminated water resulting from a series of governmental missteps. In this paper, we use the spatial distribution of lead and galvanized pipes in Flint to study the effect of the crisis on households' financial health, including loan balances, repayment of outstanding debt, and Equifax Risk Scores, as well as on household mobility. We find that relatively more affected households, as measured by exposure to lead pipes, experienced a modest increase in the balance and frequency of past due loans. Equifax Risk Scores declined slightly on average, but more so at the bottom of the Risk Score distribution. In addition, we find that there was no effect on mobility out of the state or county, but that more affected households were more likely to move within the city when the crisis began, away from lead-pipe-dense areas.

Key words: consumer finance, mobility, natural disaster

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1. Introduction

How do credit constrained communities cope with the financial consequences of environmental crises? Answering this question is critical to developing effective policies for recovery, yet very difficult to answer because most environmental crises, like natural disasters, have wide-ranging financial consequences that may occur through a variety of channels. In this paper, we study this question by examining the household credit impact of a unique environmental disaster: the Flint water crisis. In April of 2014, Flint changed its water source from the Detroit water system to a local river in an effort to save money. The water from the river was not properly treated with corrosion control; when it flowed through the city's lead pipes, lead from the pipes leached into the city's drinking water. Since the crisis began, tens of thousands of people including thousands of children have been exposed to lead-contaminated water, many of whom were impoverished and in poor health even before the crisis began.[1] In addition to quantifying an indirect mechanism through which Flint residents may have been affected by the crisis, this paper provides evidence on how credit constrained communities cope with severe adverse events.

To study this question, we combine two data sources: the New York Fed/Equifax Consumer Credit Panel, a five percent sample of the U.S. adult population, and spatial data on the distribution of pipe materials within the city of Flint from the University of Michigan (Flint). The water crisis affected all residents of Flint through a variety of mechanisms, but the extent of the impact in terms of one major danger – exposure to lead – likely depended on the type of pipes that delivered water to each household. As we will show, there is significant heterogeneity within the city in the material used to build water service lines. Lead was not the only danger generated by the change in the water source, but it was a critical one.[2] Thus, we look within the city of Flint and compare outcomes between individuals who were living in relatively lead-pipe dense areas to those living in relatively lead-pipe free areas when the crisis began.

Because all residents of the city were affected by the decision to change the water source, endogeneity of the crisis itself does not threaten the validity of our estimates. The area immediately surrounding Flint would serve as a poor control group as it is significantly wealthier and whiter than the city itself. In addition, at the time of the crisis, Flint was facing significant financial challenges and was placed under emergency management; this further complicates the identification of an appropriate control group. To overcome these challenges, we utilize within-Flint

[1] 41.2% of Flint residents live below the poverty line compared to 14.5% nationally; the average life expectancy in the county where Flint is located is 74.6 years compared to 76.3 years nationally (Census; CDC). The average Equifax Risk Score in the quarter immediately preceding the water crisis was about 630, far below the national average of 697 (New York Fed Consumer Credit Panel/Equifax).

[2] For example, there is some evidence of an increase in Legionnaires' disease as a result of the crisis (Zahran et al. (2018)).

variation in the distribution of lead pipes. Our identifying assumption is that the neighborhood-level composition of lead pipes would have had no impact on our outcomes of interest *had Flint never changed its water source*. This is an assumption that we will test by examining pre-trends in event studies. However, because we exploit within-Flint variation, our results likely underestimate the consequences of the water crisis overall.

We find that, relative to individuals in lead-free neighborhoods, individuals in lead-containing neighborhoods in Flint were more likely to have past due loans in the years following the crisis than in the years preceding it and had higher levels of delinquent loans, where delinquency is defined as at least 30 days past due on any type of debt. The majority of this effect came from an increase in mortgage balances that were 30-90 days past due; there was no increase in the rate of balances more than 90 days past due and there was no corresponding rise in foreclosures or bankruptcies attributable to lead contamination. These late loans had a small impact on Equifax Risk Score: individuals in relatively lead-dense areas were more likely to have an Equifax Risk Score below 550 a few years after the crisis, and equally less likely to have a Risk Score between 550-650. Among those with Risk Scores below 650, scores were about 10 points lower on average in 2017 through 2019 among households in 50% lead pipe neighborhoods compared to those in pipe-free neighborhoods.[3] There was no change in the distribution or level of scores among those with scores above 650. In addition, we find that the water crisis did not drive more-exposed citizens from the city, state or county at higher rates than less-exposed citizens, but it did motivate some moves within the city of Flint itself. There was a spike in address changes in 2015, the period immediately following the crisis, with people from relatively lead pipe dense areas moving to relatively lead pipe free areas.

Our results contribute primarily to three strands of literature: on the effects of the Flint water crisis, on the economic impacts of environmental crises in general, and on household credit responses to unanticipated shocks. Our paper is the first, to our knowledge, to look at the impacts of the 2014 water crisis on household finance. In terms of the health effects of the Flint water crisis, our paper complements the work of Hanna-Attisha et al. (2016), who wrote the canonical study showing an increased presence of lead in children's bloodlevels following the water switch, and that of Grossman and Slusky (2019), who show that the water crisis had a negative effect on fertility and health at birth. More recently, Danagoulian et al. (2020) study the effect of increased primary care visits generated by the Flint water crisis on subsequent emergency room demand. Pennington and Wiseman (2021) find demographic heterogeneity in effects of receiving a positive lead test on voting behavior.

[3] Between 2009 and 2019, 83% of the City of Flint had a Risk Score below 650.

Our paper is most similar to work by Christensen et al. (2019) who study the impacts of the Flint water crisis on property values and on the sale of bottled water and filtration systems ("avoidance behaviors") using a matched difference-in-differences identification strategy. In a heterogeneity analysis, they similarly exploit within-Flint variation in lead pipes, but find no differential effects comparing houses with lead pipes to those without. These two results, no differential effects on property values but differential credit responses, are not at odds with each other. For there to have been differential effects on home prices based on the material of the service lines in homes, potential buyers would have had to know where lead service lines were located. Since lead pipe mapping efforts were undertaken only in response to the water crisis, it is highly unlikely that potential home buyers would have known which homes were "tainted" and which were not, and would have treated all Flint homes with equal distaste. In our case, we claim that the presence of lead pipes proxies for lead test results that were above the legal limit, for which there exists only limited data from the peak of the crisis. Importantly, a household credit response would have been generated by the residents themselves who observed the quality of the water, not by outsiders with limited information.

Our work also contributes to literature on the household-level effects of natural disasters, including Deryugina et al. (2018) on the impacts of Hurricane Katrina in 2005, and Bleemer and van der Klaauw (2019) on the impacts of Hurricane Sandy in 2012. In contrast with this literature, and likely because the crisis made very few homes completely unlivable, we do not see moving responses out of the city, but we do see many moves within Flint. Another defining feature of our setting is the high level of poverty in Flint even before the water crisis struck, which may have severely affected individual's ability to move further away. In generally, we find statistically distinguishable but limited responses suggesting moderate strain in comparison to the results found in this literature. We also contribute to work on the household credit effects of health shocks including work by Goldsmith-Pinkham et al. (2020), Notowidigdo and Wang (2014), Barcellos and Jacobson (2015). However, much of this literature has focused on access to health insurance as a mediator to health shocks while we seek to quantify the credit response to a slightly different type of health shock. Finally, our paper is indirectly related to the literature on the effects of lead-contaminated water including work by Aizer et al. (2018), Clay et al. (2014) and Clay et al. (2019), but looks at credit rather than health outcomes. While our paper does not explicitly study these health outcomes, we hypothesize that our results are in part driven by the conclusions drawn in this literature.

The rest of the paper is organized as follows. Section 2 describes the historical background of the Flint 2014 water crisis. Section 3 describes the data. Section 4 presents the empirical strategy. Section 5 describes the main results. Section 6 presents robustness checks and section 7 concludes.

2. Background

The Flint water crisis began in April 2014 when the city implemented a decision made months earlier to change the source of the city's water supply from Detroit's water system to the Flint river (Kennedy (2016)). The move was made in an effort to reduce costs, as the city was facing a significant budget crisis. Only the city of Flint, not the entirety of Genesee County (the significantly wealthier county in which Flint lies), was affected by the change. Immediately, residents began reporting that their water was brown and foul-smelling, in addition to rashes and other physical symptoms of water-related issues (Smith (2015)). By August, water tests indicated that water quality was poor and a boil order was issued city-wide. By September, General Motors had changed the water sources for its factory, as the water from the Flint river was corroding the car parts. In February and March 2015, scientists recorded readings of 104 and 397 ppb of lead in a Flint home, the latter of which is more than 10 times the federal limit (Environmental Protection Agency (1991), Roy (2015)).

The main cause of the crisis was the failure of officials to appropriately treat water with corrosion control, which is legally required since Flint has lead pipes. This fact, combined with the problem that Flint river water is already relatively more corrosive than most drinking water sources, was the primary cause of the crisis (US District Court Eastern District of Michigan (2017b)). In part because Flint has many lead pipes, eliminating the corrosivity of the water is critical. As the water traveled through Flint's pipes, it corroded the metal and, if the pipe materials contained lead, leached lead into the water supply. Lead contamination was not the only problem. In addition to the effects on the lead content of the water, the city experienced a sharp increase in cases of E.Coli and Legionnaires' diseases during the crisis, both of which likely occurred as a result of bacteria growing where pipes have corroded and contaminated the water that passed through (Zahran et al. (2018)).

It took more than a year for city officials to admit there was a problem. In October 2015, only after a study revealing high blood lead levels in Flint children was validated by the city's own report, did the city begin to warn residents that the water was unsafe (Hanna-Attisha et al. (2016)). The city reconnected to Detroit's water supply in October 2015, but the crisis continued because the service lines had already been corroded and thus continued to leach lead into the water supply. Throughout the water crisis, there was a high level of uncertainty regarding the quality of the water due to conflicting reports and advice given by the government (Goodnough and Atkinson (2016)). In January 2016, President Obama declared a State of Emergency in Flint, freeing up resources for the state to provide bottled water, filters, and related support to Flint residents (Egan and Spangler (2016)). It was later announced that residents of Flint and former residents who may have been exposed to the contaminated water (as measured by living in Flint in April 2014) under 21 years of age or pregnant with an income below 400% of the federal poverty line are now eligible for Medicaid (Moore (2017)).

However, a permanent solution to the crisis was not a simple matter of correcting the water treatment process, which the city eventually did, or of changing the water supply to a less corrosive source, which the city also eventually did. Once pipes have been corroded, they must be replaced before the water flowing through them is completely safe; the corrosive water damaged any pipes through which it traveled and affected appliances and pipes must be replaced. The water service line replacement process is ongoing and is funded in part by the settlement of a lawsuit brought by a local organization, Concerned Pastors for Social Action, against Michigan state officials citing violations of the Safe Drinking Water Act's Lead and Copper Rule (US District Court Eastern District of Michigan (2017a)).[4] The settlement requires that:

> The City shall replace lead and galvanized steel service lines at households served by the Flint Water System as described in this Section of the Agreement...if all or part of the service line from the main line to the household water meter is discovered to be lead or galvanized steel, the City shall replace the portion(s) of the service line that are lead or galvanized steel with a copper service line at no cost to the resident or the property owner

As we will explain in detail in what follows, the data collection effort associated with this pipe replacement process motivates our identification strategy.

3. Data

We draw primarily from two datasets: the New York Fed/Equifax Consumer Credit Panel, from which we obtain data on individuals' credit outcomes and location information, and University of Michigan Flint pipe data, from which we compute census block level lead shares. Details on each dataset follow below.

[4] Concerned Pastors for Social Action is a nonprofit association of religious leaders from predominantly African Americans churches in the Flint area (ACLU).

3.1 New York Fed/Equifax Consumer Credit Panel

The Federal Reserve Bank of New York/Equifax Consumer Credit Panel (CCP) is our source for individual-level data on a wide range of financial and credit-related outcomes. The CCP contains quarterly credit records for a five percent random and representative sample of the adult U.S. population plus the household members of those individuals (Lee and van der Klaauw (2010)). Throughout, we use data as of the first quarter of each year from 2009-2019. Our variables of interest include a wide range of financial outcomes including total debt balance, total mortgage and other home-secured debt, total auto debt, and total credit card debt, as well as the amount of each of these debt types that is 30, 60, 90, 120, or more than 120 days past due. We also observe whether individuals went bankrupt or were foreclosed upon and their "Equifax Risk Score 3.0". The Equifax Risk Score is a proprietary credit score that estimates the likelihood that an individual will pay his or her debts without defaulting.

Finally, we observe a scrambled address for each individual as well as the census block of residence in each quarter. These variables allow us to study mobility both within and outside of the city. We restrict our sample to individuals who were living in Flint as of the first quarter of 2014, which is the period immediately preceding the start of the water crisis.[5] We follow these individuals throughout our sample period, regardless of whether they stay in the city of Flint because moving is endogenous to exposure. In addition, we combine CCP data with five-year American Community Survey estimates of racial composition, household income, and other characteristics at the census block group level, the finest geography for which publicly available ACS data are published.

3.2 University of Michigan Flint Pipe Data

To determine the likelihood of individuals' exposure to lead-contaminated water, we use the results of a University of Michigan Flint study on the water service line pipe composition in Flint.[6] Researchers examined the city's historical records, including hand-written records and city maps, to determine the construction material for water service lines throughout the city. There are roughly 56,000 parcels in the city of Flint; researchers identified the pipe types of approximately 75% of those using city records (99%) and field verification (1%). We aggregate this data on pipe material to the census block level by counting the number of pipes of each type in each census block. We consider lead-containing pipes to be any of the following: lead, lead-copper, lead-galvanized, galvanized, lead-plastic, lead-tubeloy, or lead-zinc. Our decision to

[5] In total, we have 4,109 individuals in our sample.

[6] Details of the effort cam be found here: https://www.umflint.edu/gis/past-projects.

consider both lead-containing and galvanized pipes as contributing to exposure is motivated by the requirement to replace all such pipes as described by the settlement reached in Concerned Pastors for Social Action et al v. Khouri et al. (US District Court Eastern District of Michigan (2017a)). We then find the share of pipes sampled that are lead-containing in each census block b:

$$\text{lead}_b = \frac{\text{number of lead and galvanized pipes}_{b,}}{\text{total pipes sampled}_b} \cdot 100$$

This value is our measure of exposure. Figure 1 shows the spatial distribution of these lead shares among census bocks that are populated by individuals observed in the New York Fed/Equifax Consumer Credit Panel[7]. The material of pipes in about 25% of parcels in Flint is unknown.[8] As a result, our measure of exposure is measured with noise and our results are likely underestimates resulting from classic attenuation bias due to this measurement error in the pipe type identification process.

Another potential source of measurement error comes from our inability to observe the pipe materials of plumbing *inside houses themselves*. The pipe classification data refers to the materials of the service lines that connect a house's pipes to the city's water system but service lines were not the only mechanisms through which individuals could be exposed. For example, one of the original whistle blowers of the crisis, Lee-Ann Walters, actually lived in a home where all pipes and appliances were certified lead-free (the pipes were made of plastic). However, the service line was made of lead, so this residence would be coded as lead-containing (Poy (2015)). While the settlement agreement maintains that the city must replace these service lines, it is up to residents to determine whether their within-home plumbing systems contain lead pipes and to replace them if they do. This introduces another source of noise in our estimates: individuals without lead service lines may have had lead-containing pipes in their home, which we do not observe. Relatedly, we do not have information on the pipe distributions of residents' schools and workplaces.

Table 1 shows summary statistics for our key outcomes and covariates dividing the sample by above and below median lead exposure. In general, homes in unexposed Flint are newer, have slightly higher valuations, and have slightly wealthier residents. However, our identification allows for level differences between the groups and requires only that had the water crisis not

[7]Most areas with missing data (where we do not observe CCP individuals living) are nonresidential. These include, for example, the University of Michigan, Mott Community College, a major highway, and the water treatment plant

[8]In our main results, we take the most conservative approach and assume all of these pipes are non-lead containing. In results available upon request, we show our findings are robust to excluding these pipes from our analysis altogether.

occurred, the trends in our outcome variables would have been the same.

4. Empirical Strategy

The purpose of our analysis is to document the household credit and mobility effects of a shock in the availability of clean water. There are a number of difficulties in identifying an appropriate control group for the city of Flint. First, the water crisis occurred shortly after the city was placed under emergency receivership due to its ongoing budget crisis which may have brought about other policies or changes that could affect credit and mobility outcomes. Had the crisis not taken place, residents of the city of Flint likely would have behaved differently than their counterparts outside the city. While there are other cities in Michigan that have been under receivership (although only one was under receivership at the same time), they are much smaller in size than Flint and thus are not appropriate counterfactuals. Second, Flint is extremely different from all of the cities and counties that immediately surround it, making a geographic regression discontinuity impossible even though there is a sharp cutoff in exposure at the city border. For example, the median income in 2014 in the Flint Public Use Microarea was around $25,000, while in the county in which Flint is located, the median income was around $47,000 (American Community Survey).

To circumvent these issues, our identification uses within-Flint variation in the exposure to lead pipes. Ideally, we would have data on lead test samples for every household beginning at the start of the crisis in April 2014. However, at the beginning of the crisis, lead sampling test kits were subject to selection bias. Flint residents were not required to submit results, and it is likely that only the most affected households are represented in lead testing results available at the peak of the crisis. Though all residents may have been affected, those with lead pipes likely had the most visible indicators that their water was unsafe for consumption.[9] In lieu of these data, we use the spatial distribution of lead and galvanized pipes.

We restrict our sample to individuals living inside the city of Flint as of the first quarter of 2014 Q1, just before the the water crisis began, all of whom were subject to the water supply shift at the same time. We exploit variation in the distribution of lead pipes throughout the city and test whether outcomes differed among individuals living in relatively lead pipe dense areas compared to those living in relatively lead-pipe free areas. We assume that the share of lead pipes in an individual's neighborhood (census block) is correlated with both the level of

[9]When a pipe is corroded, the water often brings along sediment and other materials with it, coloring the water. For example, see the comparison in water coloration as in an image in May (2016). However, we have no way to validate that such a visual indicator was more common in what we will label "treated" areas.

lead contamination experienced as well as the likelihood that an individual has lead pipes in his or her home (an "intention to treat" framework). Importantly, we do not assume a linear relationship between the share of a lead pipes in a block where an individual lives and the *extent of exposure*; rather, we assume that individuals in high-lead areas were *more likely to have been exposed*. We estimate the following:

$$y_{it} = \sum_{t=2009, t\neq 2014}^{2019} \beta_t \cdot I\{T=t\} \cdot \text{lead}_{b,2014} + \phi_i + \kappa_t + \epsilon_{i,t} \quad (1)$$

where $\text{lead}_{b,2014}$ is the lead share in census block b where individual i lived as of the first quarter of 2014. β_t are time fixed effects interacted with the initial exposure to lead-containing pipes. We estimate these coefficients relative to a baseline of the first quarter of 2014, the last quarter before the water source was changed. To control for time-invariant differences between individuals, we include person fixed effects, and to control for time trends that affected the whole city, we include year fixed effects. Because shares are estimated within a census block and the market for clean water is likely to be one's surrounding neighborhood, standard errors are clustered at the census block level which is, in practice, not too different from clustering at the individual level.

Our coefficients of interest in equation (1) are β_t, the coefficients on the interaction terms between year dummies and our measure of likely exposure to lead-containing pipes. If lead pipe exposure is independent of our outcomes prior to the crisis, then β_t will be close to 0 before 2014 and will only diverge once the exposure to lead pipes begins to affect economic outcomes, in 2014 when the water crisis began. These coefficients represent the difference in outcomes in that year between individuals living in an area with differing shares of lead service lines, reflecting a difference in the probability that they experienced adverse affects from the crisis. Thus, our underlying assumption is that absence of the introduction of highly-corrosive water into Flint's pipes, individuals in Flint would have behaved similarly regardless of the materials that made up the pipes in their homes, conditional on level differences between individuals and city-wide time trends.

5. Main Results

The following sections discuss event study results for a number of different outcome variables including overdue debt, Equifax Risk Scores, and measures of mobility. Throughout, we show 95% confidence intervals. Each coefficient represents the difference in the outcome variable in that year for an individual living in a 25% lead share (which is the standard deviation of lead share in Flint) neighborhood as compared with someone living in a lead-free area.

5.1 Payments on Existing Debt

First, we estimate equation (1) looking at outcomes including amount of debt that is delinquent (at least 30 days past due) and the amount that is severely derogatory (more than 120 days past due). We estimate results both for the levels of outstanding debt balances, as well on indicators for whether an individual has any derogatory debt, in order to determine whether any effects are coming from a change in the fraction of individuals with outstanding loans or a change in the level of outstanding derogatory debt. These results are presented in Figure 2. In panel (a), we see an increase in both the level and frequency of overdue debt; this increase is concentrated among non-derogatory loans. A mild increase begins immediately following the start of the crisis but does not become statistically significant until 2017. Comparing households in lead pipe free areas to those in lead pipe dense areas, affected households were about 2% more likely to have a delinquent loan by 2018. In terms of levels, more affected household had roughly $500 past due by 2016, though it declined again and has nearly returned to its pre-crisis level. The median family income in Flint was around $24,000 per year (American Community Survey) in 2014, so a $500 debt represents about 2% of the median family's annual income. Figure 4 shows estimates for bankruptcy and foreclosure; we find no statistically significant effects on these outcomes.

In panel (b) of Figure 2, we look at some components of the total overdue balance: student debt, auto debt, credit card debt, and mortgage debt.[10] Most of the effect on total balance past due is coming from past due mortgage and student debt balances: in 2017, an affected household had about an additional $300 in mortgage debt past due and roughly $100 past due of student debt. The remainder of the magnitude of the effect on overall balance past due is likely coming from the combination of other categories. In results available upon request, we do not find any effects on the level of mortgage balance, suggesting that the increase in mortgage balance past due is not a function of higher overall mortgage balances. These results suggest that constrained borrowers may have prioritized paying down credit card and auto debts, as these carry higher interest rates and greater punishments for short-term delinquency (e.g. repossession) than mortgages or student loans.

[10]Total balance also includes retail card balance, consumer finance balance, home equity line of credit, and home equity installment loan, though these categories make up a lower share of total balance and we find no effects of the water crisis on these balances.

5.2 Equifax Risk Scores

Delinquent loans have consequences for individuals' Risk Scores, which affect their ability to borrow in the future. Figure 5 shows the effects on the level and distribution of Risk Scores. In Figure 5a, we show changes in the probability of an individual having an Equifax Risk Score in the following categories: 300-550, 550-650, 650-750, and 750-850. We find, by 2018, that an individual in a 25% lead pipe area was about 2% more likely to have a Risk Score in the lowest category and is also 3% less likely to have a Risk Score between 550 and 650 although these estimates are only marginally significant. This suggests that affected individuals with relatively high Equifax Risk Scores were more likely to experience the negative economic consequences of the water crisis, but that the effects on Risk Score were not extremely large. This is consistent with our overdue debt results, since it is more likely that individuals with access to credit (who thus were more at risk of becoming delinquent on their debt) had initial scores between 550-650. We see no effects on the probability of having an Equifax Risk Score between 650 and 750, or above 750. In figure 5b, we show the effect on the level of Risk Score. The effect on the whole sample (available on request) is zero, but this masks substantial heterogeneity. Among those whose initial, pre-crisis Risk Score was below 600, Risk Scores fell by 6-12 points for an affected household while there was no effect among those with a Risk Score above 600. These effects on Equifax Risk Scores are not economically very large, but they point to the small negative consequences of even slightly overdue loans.

5.3 Mobility

The CCP also includes data on individual mobility, as it includes not only quarterly information on census block of residence, but also a scrambled address that changes when an individual's address changes. This allows us to track the frequency of both short distance and long-distance moves. Mobility is not only an important outcome in this setting, but it is also closely related to individuals' financial health. The ability to respond to the crisis by moving out of the troubled area may have been substantially hindered by individuals' access to credit, as we will investigate.

To the extent that the water crisis made life sufficiently unbearable, individuals may have opted to move out of Flint altogether. We investigate these hypotheses empirically, first estimating equation 1 where the outcome variable is a indicator variable taking on a value of 1 in year t if an individual has a different address than year $t-1$. Results are in figure 6. We find a sharp increase in the probability of moving in 2015, the year immediately following the start of the crisis, but we find no evidence that this effect is generated by individuals moving out of the state or out of the county. Instead, moves are made within the City of Flint. These null effects on out-of-state and out-of-county moves may be attributable to the costs associated with moving and uncertainty over whether or not the water in Flint was indeed safe to drink. Because the entire city was affected, it is not immediately obvious why moving within the city would be advantageous. But we find that individuals were moving from "high-lead areas" to "low-lead areas": in the lower right panel of figure 6 shows, among the individuals who moved in 2015, the change in the lead exposure in their census block of residence. The effect is stark: individuals living in high-lead areas were more likely to move to lower-lead areas immediately following the crisis relative to those living in low-lead areas.

6. Robustness

6.1 Age of Home

One concern with our results may be that we are capturing not only the effects of the lead contamination, but also the effects of, for example, home deterioration, on behavior since lead pipes are more common in older and less valuable homes. Potentially, people living in these homes may be lower-income and more likely to have trouble paying down their existing debt. While most of these concerns are alleviated due to the absence of pre-trends in our main results, it could be that the timing of the water crisis was correlated with city-wide financial distress that affected residents of different types of homes differently regardless of the materials of the pipes. To test for this, we replicate our primary results including year by median home age fixed effects, where median home age is determined by the census block group in which an individual lived in 2014 Q1 using data from the American Community Survey. By doing so, we partial out any effects that change over time and that are generated not by exposure to lead but instead by exposure to a "relatively worse" home as proxied by the average age of the homes in the census block group where an individual was living as of 2014 Q1.[11] We estimate:

$$y_{it} = \sum_{t=2009, t\neq 2014}^{2018} \beta_t \cdot I\{T=t\} \cdot \text{lead}_{b,2014} + \alpha_t \cdot I\{T=t\} \cdot \text{age of home}_{b,2014} + \phi_i + \kappa_t + \epsilon_{i,t} \quad (2)$$

We plot β_t in Figure 8. If in fact the lead share is providing information beyond proxying for age or quality of home, we would expect our main results to be robust to including this control.

[11] As in our standard measure of lead exposure, we fix the age of home based on the pre-crisis census block of residence because moving is endogenous.

Results of this estimation are shown in Figure 8. We find that that adding age of home by year fixed effects has little qualitative impact on our main results, though our results on Equifax Risk Scores get a bit noisier due to the increased demand on the data by adding this additional set of ten fixed effects. While the magnitudes of the Risk Score results remain very similar, the standard error bars grow considerably.

6.2 Permutation Tests

To test whether the magnitudes of our main results could have been generated by chance instead of by the impact of differential lead pipe exposure, we construct permutation tests. These tests involve randomly assigning each census block a lead share from the original data without replacement. We repeated this exercise several times to generate a distribution of treatment effects. The results of this exercise are presented in Figure 9. The graphs are organized as follows: the bold line presents our estimate, the numbers next to each point on the bold line show the percentile of the bootstrapped null distribution to which the point estimate corresponds (e.g. p96 means that the point estimate is larger than 96% of the estimates when lead share is assigned at random). Finally, the shaded regions represent the centered sets of the null distribution containing 95% and 97.5% of its mass, respectively.

In Figure 9a, we show permutation tests of our results on the level and frequency of past due loans results. In 2017 through 2019, the increase in the amount of balance past due us well outside out confidence interval of what could be obtained with a placebo lead share. In Figure 9b we do the same with our Equifax Risk Score outcomes. Similarly, for both the level and distribution of Risk Score, find that our results could not have been generated by random chance. Finally, Figure 9c shows permutation tests on our mobility outcomes and we reach the same conclusion. This exercise suggests that our lead exposure is meaningful and is indeed capturing differences in post-crisis trends across the lead exposure distribution.

6.3 Comparison to Boston

Another explanation for our results is that there was an unobserved nationwide shock in 2014 that may have affected individuals differently based on their lead pipe exposure. To test this, we replicate our Flint results using data on another city. However, there is limited availability of data on the presence and location of lead service pipes in other cities. Thus, to test whether the effects we find could be generated by other, non-water crisis differences between lead and non-lead households, we repeat our analysis using data from Boston. While we do not claim that

Boston is in any way similar to Flint, the data available for Boston allow us to replicate our Flint study exactly.[12] We start by geocoding all of the addresses using the US Census geocoder. Then, we compute the number of addresses in each census block and the number of addresses with lead pipes in each census block. We construct our usual measure of lead exposure by dividing the number of lead-pipe addresses by the total number of addresses for each census block. Then, we repeat our analysis. Results of this exercise are shown in Figure (10). Fortunately, we do not obtain similar results: there is no differential trend in any of our outcome variables before or after 2014 among more or less lead exposed areas in Boston.[13]

7. Conclusion

Using data on the credit histories of 5% of the U.S. population together with within-Flint variation in lead pipe density, we estimate the effects of the Flint water crisis on credit access, borrowing, and household mobility. We find that more exposed individuals saw an increase in debt past due and a decline in credit scores, with greater credit score declines for people lower in the credit score distribution. We also find that more exposed individuals were much more likely to move within Flint to a less lead-exposed location. Our estimates should be treated as lower bounds on the effects of the crisis as a whole on these outcomes, because we rely on within-Flint variation and cannot capture financial effects of the water crisis on all residents regardless of their exposure to lead. Our results are important for two reasons. First, we provide evidence of another mechanism through which residents of Flint were affected by the water crisis. Second, our results complement the growing literature on the household credit consequences of environmental disasters. While we do not find long-term adverse effects on household finances, the effects we find are consistent with substantial harms to a vulnerable group.

[12] Data on the location of lead pipes in Boston can be found here: https://www.bwsc.org/environment-education/maproom/lead-service-map

[13] It is plausible that we could have found effects on mobility in Boston driven by the Flint water crisis. As the water crisis drew attention to lead in pipes in the entire country, residents of lead pipe households in other cities may have been more likely to move. However, we find no evidence of this in the case of Boston.

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8. Tables and Figures

Figure 1: Flint Lead-Containing Pipes Among CCP-Populated Blocks

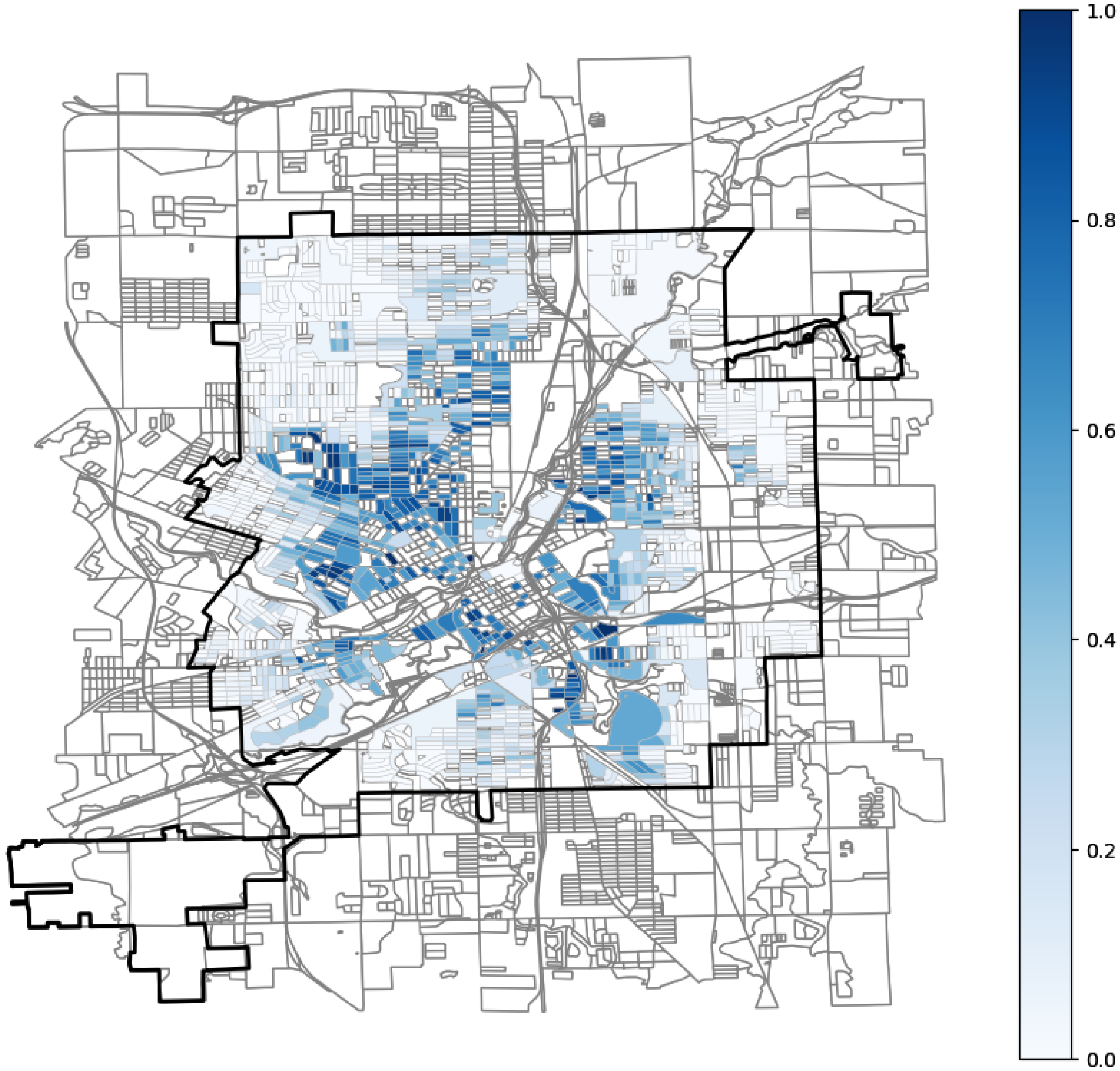


Figure (1) shows our source of variation, lead_b. Darker blue indicates that a census block has a high share of buildings with lead service pipes. We compute lead share for block b as $\text{lead}_b = \frac{\text{parcels with lead or galvanized pipes in } b}{\text{total sampled parcels in } b}$.
Source: University of Michigan Flint, US Census, and authors' calculations.

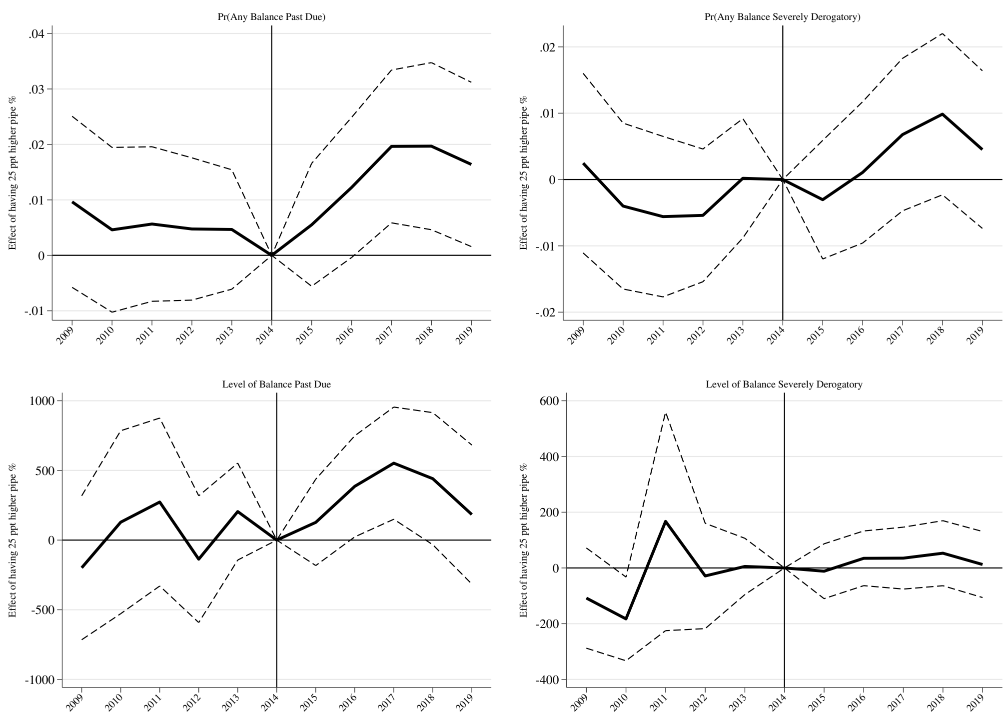
Table 1: Summary Statistics: Before Water Crisis (2014)

	Exposed Flint		Unexposed Flint	
Riskscore	627.97	[107.33]	633.7	[109.23]
Homeowner	.08	[.272]	.124***	[.33]
Total Balance	11414	[25143]	17449***	[36298]
Mortgage and Heloan Balance	3,752	[16688]	6,672***	[26734]
Auto Loan Balance	1,708	[5,207]	2,734***	[6,705]
Credit Card Balance	905.14	[3,692]	1,368**	[4,947]
Student Loans	4,314	[13035]	5,541*	[17124]
Home Equity Revolving Balance	344.66	[4,439]	281.74	[3,575]
Total Balance Past Due	1,804	[8,563]	3,192*	[20103]
Any Balance Past Due	.166	[.372]	.215***	[.411]
Level of Mortgage Balance Past Due	283.01	[4,521]	1,100	[16947]
Any Mortgage Balance Past Due	4.8e-03	[.069]	.014**	[.116]
Amount of Auto Balance Past Due	341.58	[2,039]	384.38	[2,244]
Auto Balance Past Due	.035	[.185]	.044	[.204]
Amount of Credit Card Balance Past Due	154.92	[1,502]	183.49	[1,248]
Credit Card Balance Past Due	.059	[.235]	.069	[.254]
Amount of Student Loans Past Due	948.9	[6,148]	1,175	[7,802]
Student Loans Past Due	.067	[.251]	.078	[.268]
All Other Balances Past Due	.037	[.19]	.055*	[.227]
Amount of All Other Balances Past Due	58.495	[532.62]	132.54	[1,445]
Declare Bankruptcy	.078	[.269]	.095	[.293]
Foreclosure	.021	[.144]	.036**	[.187]
Share of pipes lead or galvanized	.538	[.212]	.029***	[.05]
Share on Medicaid	.488	[.171]	.456***	[.154]
Share African-American	.54	[.356]	.57**	[.345]
Share White	.393	[.332]	.378	[.334]
Median Year Built	1948	[8.2915]	1957***	[7.809]
Median Rent	707.49	[179.53]	751***	[170]
Median Household Income	26180	[12895]	29944***	[12677]
Median Home Value	30824	[20384]	36556***	[19760]
Median Age of Home	65.898	[8.2915]	56.609***	[7.809]
Move (Change Address)	.065	[.246]	.092**	[.288]
Move Out of County	.016	[.125]	.019	[.138]
Number of Household Members	2.7861	[1.7202]	2.9019*	[1.6509]
Share of Household Members Over 65 yrs	.203	[.326]	.23*	[.331]
Share of Household Members Under 25 yrs	.089	[.193]	.102*	[.207]
N	1468		2641	

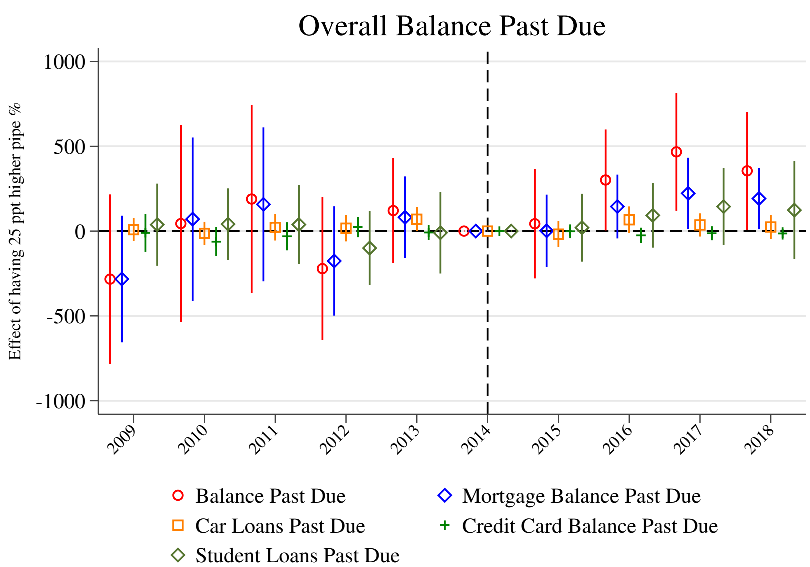
Source: New York Fed Consumer Credit Panel/Equifax, American Community Survey, and University of Michigan at Flint. Standard deviations are in brackets. Sample is individuals who lived in the city of Flint as of Q1 2014, the last period before the water crisis began, and values include those across the entire sample period 2009-2019. Demographic variables represent the value associated with the census block or census block group in which the individual lived as of Q1 2014. Exposure is based on whether 10% or more of the pipes in the census block of residence are lead-containing.

Figure 2: Overdue Debt

(a)

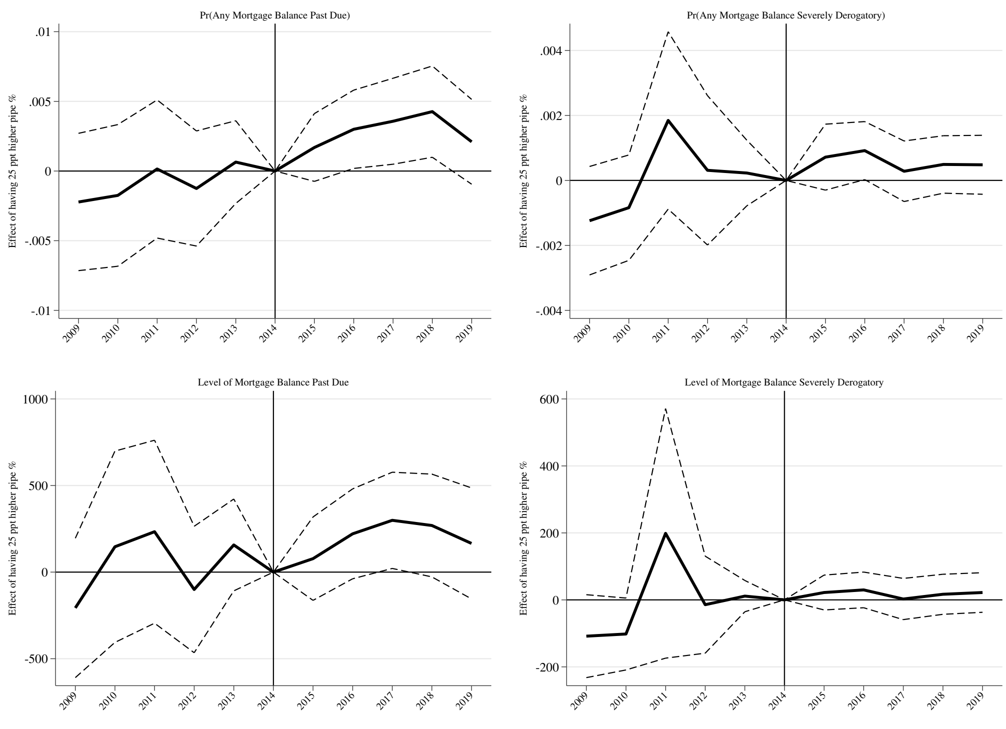


(b)



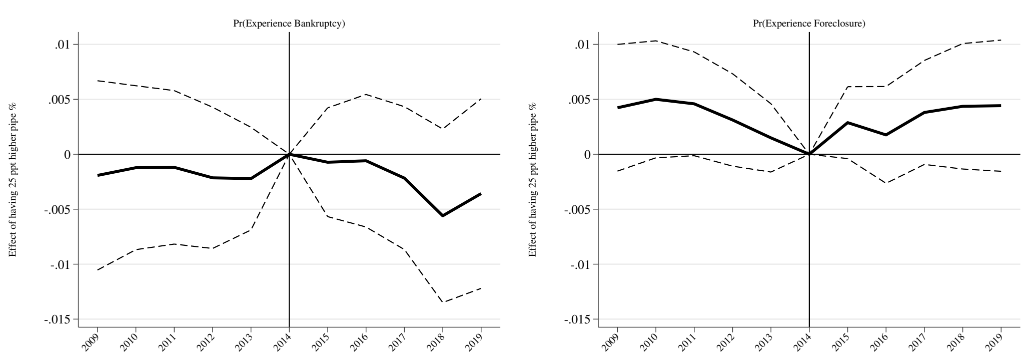
Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group.
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

Figure 3: Overdue Mortgage Debt



Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group.
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

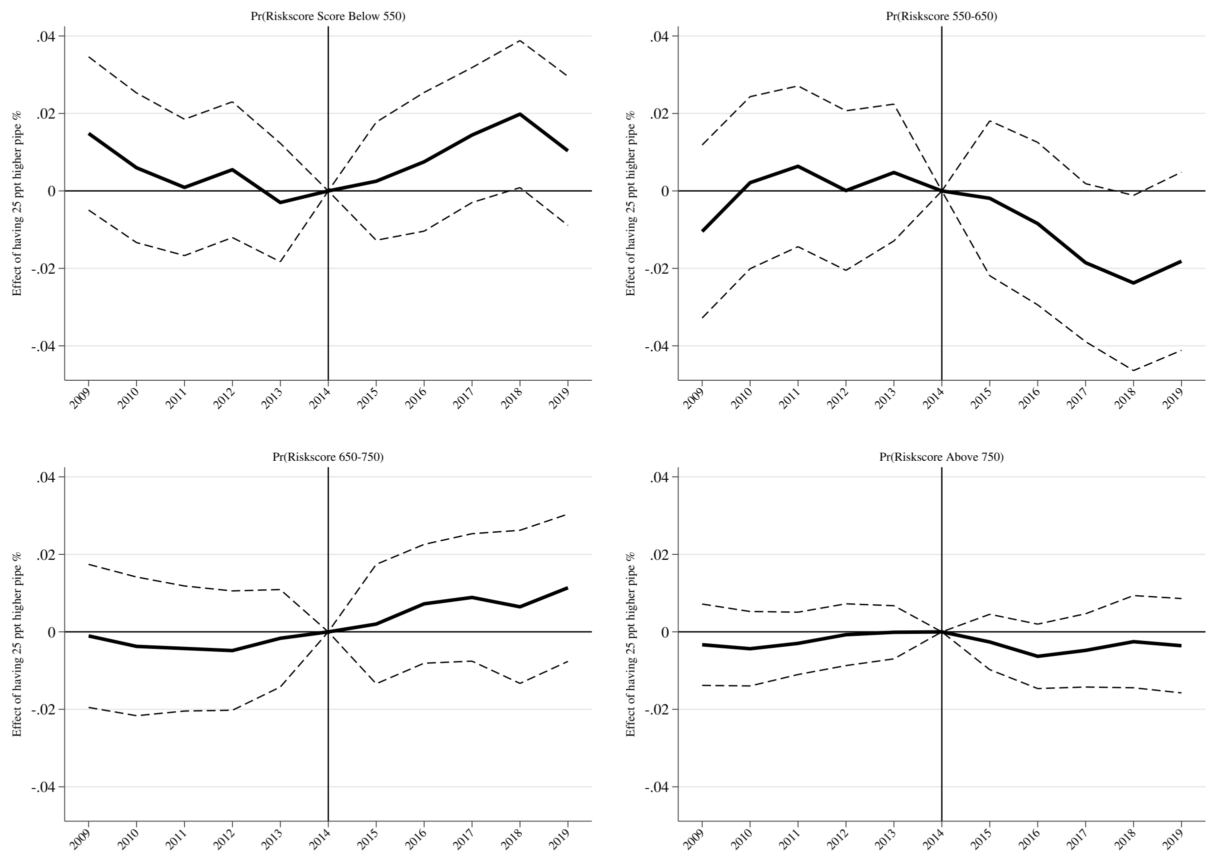
Figure 4: Bankruptcy and Foreclosure



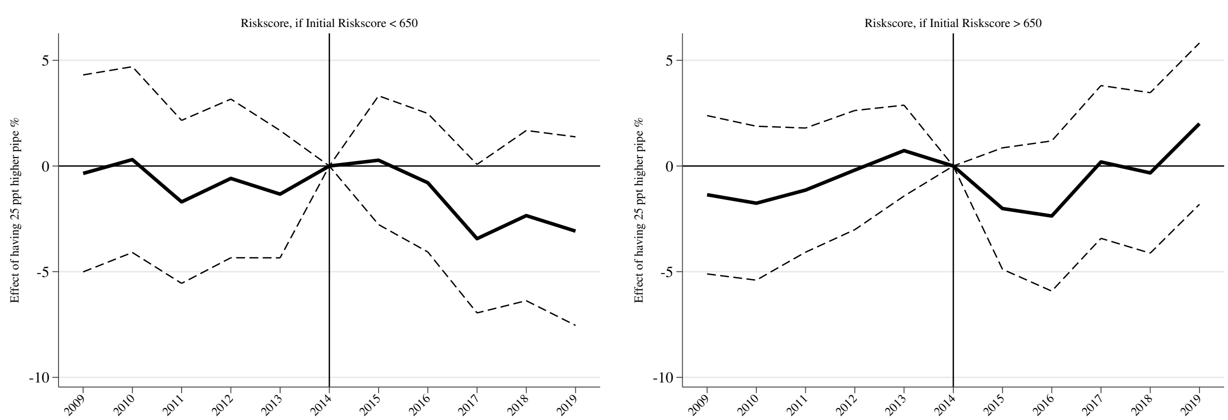
Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group.
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

Figure 5: Credit Score*

(a) Pr(Credit Score* Bin)

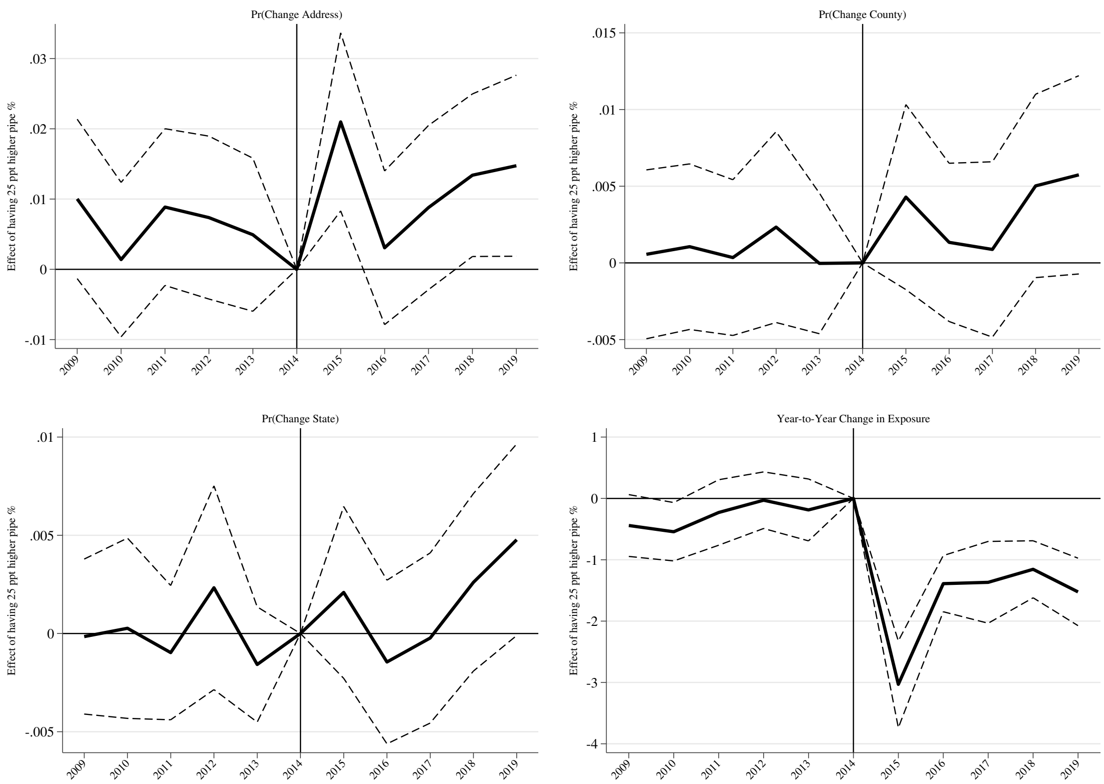


(b) Level of Credit Score*



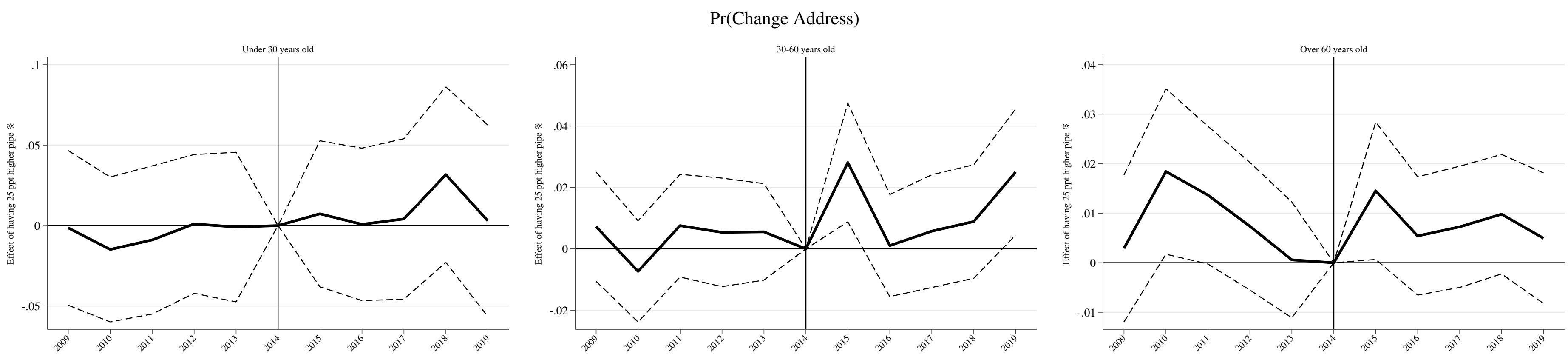
Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group. *Credit Score is Equifax Risk Score 3.0
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

Figure 6: Mobility



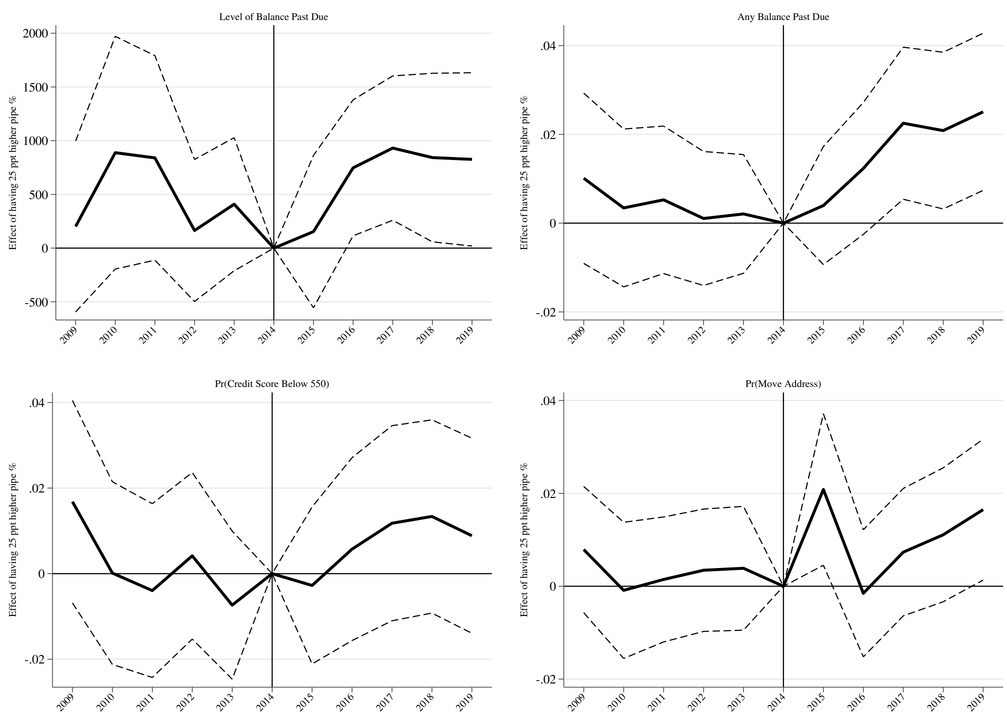
Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group.
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

Figure 7: Mobility By Age Group



Note: This is a plot of the estimates of coefficients β_t from equation (1) with 95-percent confidence intervals clustered on the census block group.
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

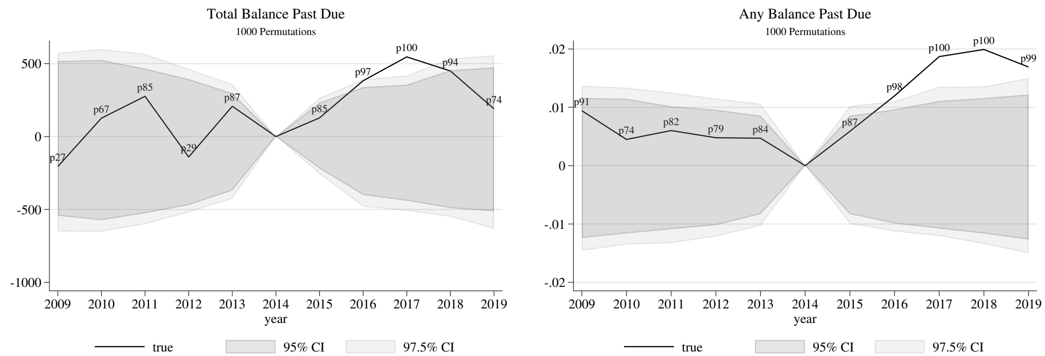
Figure 8: Robustness: Including Age of Home×Year FE



Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, ACS, and author's calculations.

Figure 9: Permutation Tests

(a)



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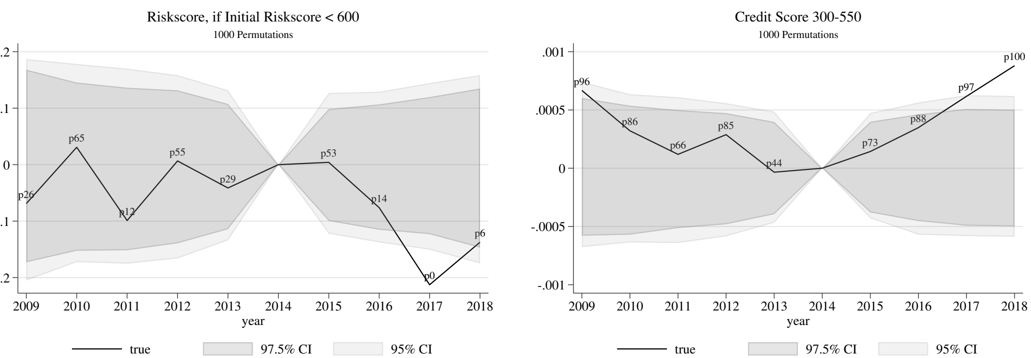
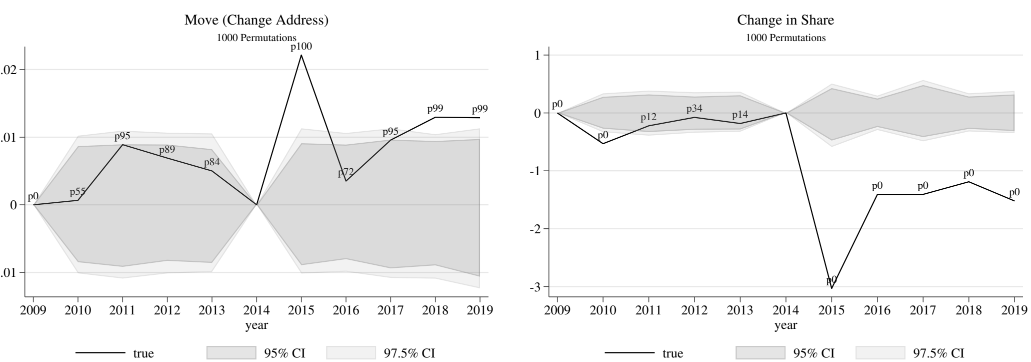


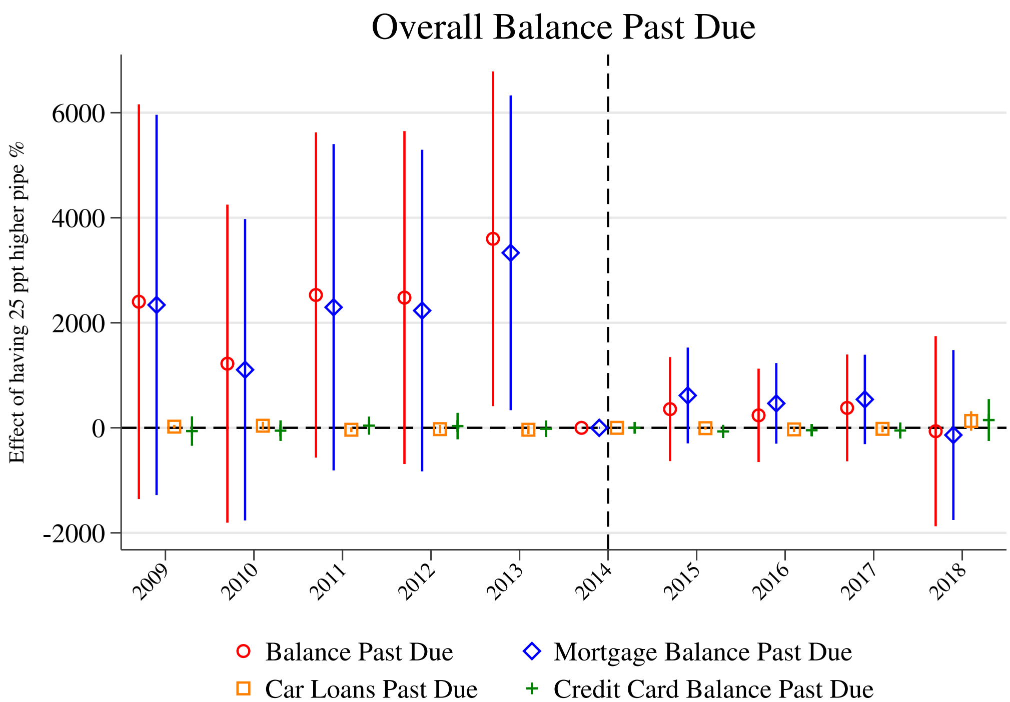
(c)



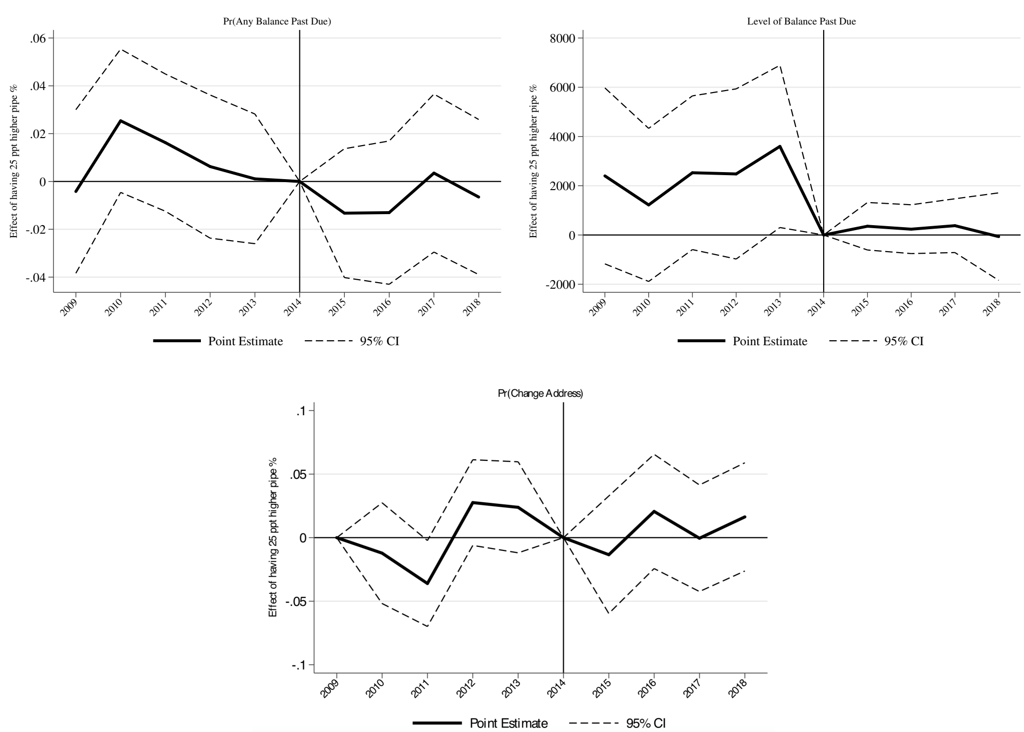
Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.

Figure 10: Boston Comparison

(a)



(b)



Source: University of Michigan Flint, New York Fed Consumer Credit Panel/Equifax, and author's calculations.