THE MEDIATION EFFECT OF INDOOR AIR QUALITY ON HEALTH:

A COMPARISON OF HOMEOWNERS AND RENTERS

by

SEONGSU KIM

(Under the Direction of Andrew T. Carswell)

ABSTRACT

The purpose of this research is to explore whether there is a health disparity between homeowners and renters affected by the indoor air quality of their dwellings. By proxying the presence of mold and smoke as facilitators of poor indoor air quality, I designed a mediation model that previously has not been explored quantitatively. The structural path model in this study shows that there is indeed a disparity in health between urban homeowners and renters by demography, socioeconomic status, and dwelling condition. Built upon the notion of environmental injustice and housing adjustment theory, this study argues that renters whose living conditions generally are worse off than homeowners are also unequal in their health status due to exacerbating effects coming from poor indoor air quality, which is endogenous to the condition of the urban renter. The originality of this study is that it is the first study that empirically tests the mediation effect of poor indoor air quality of homeowners and renters using a structural equation mediation model.

INDEX WORDS: Health of urban dwellers, Housing, Indoor air quality, Mediation effect, Mold and smoke.

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DEDICATION

I dedicate this dissertation to my late grandparents who were proud Americans and respected members of the Denver, CO, Korean American community.

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"Fear not, for I *am* with you; Be not dismayed, for I *am* your God. I will strengthen you, Yes, I will help you, I will uphold you with My righteous right hand."

Isaiah 41:10 (New King James Version).

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CHAPTER 1

INTRODUCTION

As of 2018, about 82 percent of the North American population lives in urban regions compared to 74 percent in Europe or 50 percent in Asia (United Nations (UN), 2018). Also, more than a third of U.S. households live in rental housings (Joint Center for Housing Studies of Harvard University (JCHS), 2017) and rental housing is more prevalent in urban areas, whereby more than half of the air intake is inhaled in homes (Sundell, 2004). Thus, indoor air quality remains a persistent issue with renter households, particularly low-income households due to the denser environment of a renter's living arrangement.

The primary purpose of this study is to measure the disparity of health between homeowners and renters. To my best knowledge, there has been little done about the discrepancies between homeowners and renters in terms of poor indoor air quality. In the United States, previous studies have found that poor air quality triggers disparities in respiratory health (e.g., Maantay, 2007), school absenteeism (e.g., Gilliland et al., 2000), and emergency room visits (e.g., Zhu, Carlin, & Gelfand, 2003). In most cases, these studies explored racial as well as income differences, yet the difference between homeowners and renters was not elaborated enough. The closest to this study was done by Grineski (2008), who qualitatively compared renters with Section 8 vouchers and those who are living in public housing. Thus, there has not been a study that quantitatively analyzed the differences between health and indoor air quality by homeowner and renter.

In a dense living environment, mold and dampness (Bonner, Matte, Fagan, Andreopoulos, & Evans, 2006), tobacco smoke (Crain et al., 2002); furry pets, cockroaches, dust mites, rodents (Lanphear, Aligne, Auinger, Weitzman, & Byrd, 2001), and odorous chemicals (Tsai et al., 2006) have been found to trigger respiratory illnesses. Of these, two of the biggest determinants of poor indoor air quality are smoking and the presence of mold. Within such a cramped environment, the presence of a smoker or second-hand smoke can prove harmful to the health of all household members. Also, the presence of excess moisture in the dwelling may cause musty smells, which triggers asthmatic or other respiratory health concerns to the household.

It has been well documented that environmentally unequal habitats have triggered symptoms of respiratory illness, obesity, diabetes, and a range of other illnesses (Landrigan, Rauh, & Galvez, 2010). In line with the various findings in the past, the research question of this study tries to answer whether there are health disparities between homeowners and renters caused by poor indoor air quality. Recent studies (JCHS, 2018, 2019) have found that the current state of low-rent dwellings consists of mostly older buildings that come from the low supply of housing stocks for the low-income population. While the supply of housing in the rental market steadily has been increasing since the Great Recession, due to the increasing cost of construction and labor, new constructions mostly pertained to high-income earners. Also, while for homeowners, the housing cost burden mostly declined, about half the renters remained cost-burdened. Furthermore, households with income less than $15,000 continued to pay more than 30 percent of their income towards housing, and 72 percent of them paid more than 50 percent (JCHS, 2019). Indeed, there is a disparity in terms of whether one is a homeowner or renter, and this difference also facilitates different health outcomes (e.g., Mulder, 2004).

The background of my research is based on an environmental activism called environmental injustice. I elaborate further using the housing adjustment theory (Morris & Winter, 1996) In this study, I assess differences between homeowners and renters in terms of their given socioeconomic status and housing condition and hypothesize that poor indoor air quality would deteriorate the health of the renter more than the homeowner. The theoretical model of the housing adjustment theory resides in a mediation framework where exogenously given housing, and socioeconomic variables of a homeowner or renter are linked to one's health condition, while mediated through the endogenously generated poor indoor air quality (proxied by the presence of mold and smoke).

A similar mediation model was suggested by Rauh, Landrigan, and Claudio (2008), yet their study was not a quantitative one (see Appendix). Rauh, Landrigan, and Claudio (2008) argue that the mediation effect of environmental hazards is a mediator between one's dwelling as well as the socio-physical status and health outcome. This conceptual mediation model can be stratified from a social/structural, neighborhood, and individual/family level perspective, whereby this study comprises all levels in terms of the sample type and the individual/family level regarding the variables used in the empirical model.

In terms of the methodological approach used in this research, little has been done using a mediation path analysis. Even though mold or smoke are significant signals of poor indoor air quality, previous studies only used them in a simple regression framework that only measured the association between one's health and indicators of poor indoor air quality (e.g., Dales, Miller, & McMullen, 1997). The lack of an endogenous process that involves one's housing tenure and health was not elaborated enough in terms of a systematic sequential framework by how one's health deteriorates, given the socioeconomic as well as the physical environment in which one resides.

With the help of the 2011 version of the American Housing Survey (AHS), I have analyzed the direct, indirect, and total effects of the homeowner and renter's health. The indoor air quality variables for this analysis were composed by whether there was a smoker in the household or a frequent visitor to the unit who smokes. There was also a series of questions in the data related to the presence of excess moisture at homes such as musty smell and the actual presence of mold. Based on these variables, I have developed a structural equation (mediation) model that included exogenous variables related to race, socioeconomic status, housing condition, and the intervention effort of the dwelling occupant.

The primary finding of my research specifically shows that the mediation effect of poor indoor air quality differs by homeowner and renter in the sense that the negative health outcome of the renter was greater than that of the homeowner. Consistently, when mediated through poor indoor air quality, the exogenous variables showed a greater deteriorating health effect in the renter's sample as compared to the homeowner. The most prominent and consistent results were found in the variables related to the resident's low-income and low-education status that showed a strong mediated indirect effect, whereby the renter more experienced environmental injustice than the homeowner. This disparity in health between the homeowner and renter was observed consistently throughout all the analyses in this study. The finding of low income and education directs to the fact that health deterioration through poor indoor air quality is more of a social product rather than being a physical outcome of age or race, whereby a residential adjustment through maintenance and intervention effort in response to poor indoor air quality would benefit the renter more than the homeowner.

The structure of this study following this chapter builds on the literature review, empirical analysis, conclusion, and discussion. There are two major sections in the literature review chapter, where each of them comprises three subsections. The first section in the literature review discusses the notion of environmental injustice, which is then followed by the second section, where I elaborate on the housing adjustment theory. In the empirical analysis chapter, I start with the introduction of the data and empirical models that I have used and continue with the interpretations of the direct, indirect, and total effects. The fourth chapter concludes and summarizes my findings and suggests directions for future research. This is then followed by the discussion chapter, where I make several arguments as to why the results of this study matter.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Environmental injustice

In 1994, President Clinton signed the Environmental Justice Executive Order 12898 and mandated that federal agencies should focus on environmental justice to address health policies pertinent to minority and low-income populations (Rauh, Landrigan, & Claudio, 2008). In this executive order, environmental justice is defined as follows:

> “The fair treatment and meaningful involvement of all people regardless of race, ethnicity, income, national origin or educational level with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate burden of the negative human health or environmental impacts of pollution or other environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local and tribal programs and policies.”

In many cases, environmental injustice is used interchangeably with environmental inequality. The motion or pursuit of equality is then described as what we call environmental equality or justice. The underlying assumption of environmental injustice is that one’s socioeconomic status aligns with its environmental quality. Thus, lower socioeconomic status relates to a lower quality of living standards. Evans and Kantrowitz (2002) provide an overview of the theoretical background of what constitutes environmental injustice. They submit that the socioeconomic status of the low-income population is mediated through the ambient environmental condition, which together affects a resident's health. Here, previous literature categorized groups of minorities or individuals below the poverty line as people coming from low socioeconomic backgrounds. Thus, the salient argument of Evans and Kantrowitz'es (2002) theoretical model on environmental injustice argues that low income or socioeconomic status brings exposure to toxins, pollutants, noise, crowded dwellings, or the lowest quality of housing, neighborhoods, and schools. It is noted that the theoretical outcome of environmental injustice strongly relates to the health outcome of its residents. That is, it is not only a notion that connects one's socioeconomic status with the environment but also the outcome of this connection, which is the health status of the underrepresented population. Regarding indoor air quality, Evans and Kantrowitz (2002) further argue that the risk of poor indoor air quality is mostly found in rental units, dwellings of occupants with low education, or single parenthood.

Environmental injustice is also called spatial inequality and assumes that the land rent is different among socioeconomic statuses (e.g., Buzzelli, Jerrett, Burnett, & Finklestein, 2008). Yet, it is still debated whether the presence of low-income residents or the environmental hazard was located first in the low-rent area. Because the land rent is lower than other areas of the urban landscape, it is plausible that lower-income people were already present in those areas, followed by the placement of the hazardous environment. However, it is also possible that the low socioeconomic population placed themselves into an area with environmental hazards because the land rent was already low. Regarding the sequence and whether the underrepresented population was forced or self-selected themselves into an area remains a task for future research. However, regardless of when the low-income population was present, it remains obvious that a hazardous environment causes dreadful health issues to the population that is living in that area.

In an American setting, it goes without question that health outcomes go with the unequal wealth distribution among racial groups (Deaton & Lubotsky, 2003). In this sense, most of the previous literature tried to illuminate environmental injustice in terms of income disparity between race groups. Even though there are mixed findings on whether racial discrimination is indeed the root cause of environmental injustice, the mainstream of previous literature goes into the direction of racial segregation in dwellings and its associated environmental differences and health outcomes. For this reason, pertinent to racial disparities, environmental injustice is sometimes termed environmental racism.

However, there is not much evidence that there is an institutionalized agenda based on race. An example is provided by Bowen, Salling and Haynes, and Cyran (1995), who have investigated the Cleveland, OH area for spatial discrimination and found that there is no solid evidence for such claims. Despite the findings that racial, as well as income disparities, are strongly correlated with environmental injustice, Downey, Dubois, Hawkins, and Walker (2008) find strong evidence that previous predictors of environmental injustice do not sufficiently deliver the notion of discrimination. In their study of 329 metropolitan areas in the United States, they find that there is weak evidence that minority and lower-income groups are affected by environmental injustice. The authors (Downey, Dubois, Hawkins, & Walker, 2008) argue that residential segregation or income inequality are poor predictors of environmental injustice. This is because segregated areas are artificially set boundaries and are fundamentally different boundaries compared to the physical proximity to the origin of pollution. For example, a wealthy neighborhood would have the same exposure to pollutants as less-wealthy neighborhoods when it is located at the same distance to the origin of pollution. In a similar study, Finkelstein, Jarrett, and Sears (2005) found that gaseous pollutants coming from nearby traffic equally affected the rich and poor areas so that the mortality rate was not significantly different from each other.

About environmental injustice and indoor air quality in the United States, in Michigan, Mohai, Kweon, Lee, and Ard (2011) found that pollution around schools is linked to poorer student health and academic performances. In a similar study, Pastor, Morello-Frosch, and Sadd (2005) found that students living close to toxic air emission sites were behind the standard academic performance level. In this study, they investigated the spatial patterns of land use by locations of toxic emissions and calculated the cancer risk and respiratory hazards of toxic air emissions by school districts in Los Angeles, CA. Their result showed that schools with a greater percentage of minorities have a greater chance of having children with cancer or respiratory diseases. Similarly, Apelberg, Buckley, and White (2015) conducted a study evaluating the disparities among socioeconomic groups in Maryland. They investigated cancerous air toxins at the census tract level and found that there is a significant association of exposure to toxins by racial groups and further found that cancer risk was increasing when African Americans were living in that area. In a study in Miami, FL, Grineski, Collins, Chakraborty, and McDonald (2013) found that children's hospitalization with asthma showed a significant association with being a child of a female-headed householder and being in a low-income bracket. Another study by Grineski (2008) compared asthma disparities among people living in federally subsidized housing units in Phoenix, AZ. In her study, she compared families living in public housing with renters with Section 8 vouchers and found that renters with an option to move to a place with a better environment (i.e., Section 8 voucher recipients) suffered less from poor indoor air quality, and therefore reported a lower rate of asthma. The underlying treatment effect in this study is based on the assumption that many of the public housing projects are close to industrialized zones, and therefore are exposed to more environmental inequalities (Cutter, Hodgson, & Dow, 2001). In a similar context, in Atlanta, GA, Zhu, Carlin, and Gelfand (2003) found that, during the summers of 1993 and 1995, lower socioeconomic statuses and a high percentage of African American children in a certain Zipcode area were predicted to have visited the emergency room due to asthma.

More evidence on environmental injustice was found by Jacobs (2011), who found that residents living in the City of New York's social housing have a significantly different morbidity rate than residents who do not. Jacobs (2011) adds that health problems were exacerbated when the occupant was coming from a low-income household and was a minority and that this problem has been persistently observed in the last three decades. Another evidence in the State of New York was found by Raugh, Chew, and Garfinkel (2002), who conducted a study on cockroach allergens. The authors (Raugh, Chew, & Garfinkel, 2002) used a small sample of African and Latin Americans in Northern Manhattan, NY, and found that indoor allergen levels induced by cockroaches were closely related to units that need more maintenance.

International studies show that environmental injustice remains an issue in other countries as well. And, even though many papers deliver the same message, it is important to note that the situation in the United States differs from other countries. Countries such as Canada, the United Kingdom, Germany, or France are also diverse to a certain degree, yet the racial/ethnical constitution and the entailed historical, as well as economic context, is different from ours. Another difference that should be noted is the healthcare system. Given the absence of a universal healthcare system in the United States, a health comparison with other countries would not be commensurable to the social and environmental injustice discussed in the United States in the sense that comparison in an economic framework should only be restricted to almost identical treatment and control groups.

Development of indoor air quality as a public health issue

According to the United States Environmental Protection Agency, indoor air refers to the quality of the air within and around building structures, whereby the notion of quality is linked to the health and comfort of the building occupants (U.S. Department of Health and Human Services (HHS), 2009). Regarding environmental inequality in terms of indoor air quality, the U.S. Surgeon General (HHS, 2009) notes that it should be addressed at the community level yet does also acknowledge that the available resources are insufficient to implement a local solution related to healthy homes.

The U.S. Surgeon General (HHS, 2009) documents that the source of poor indoor air quality can come from combustion appliances, tobacco products, building materials, central heating/cooling systems, excess moisture, or outdoor sources such as radon, pesticides, or pollution. Immediate effects of indoor air pollution include symptoms that emerge shortly after a single exposure and include irritations of the eyes, nose, and throat. A long-term health effect from poor indoor air quality is defined as having a health effect after repeated exposure over several years. Long-term health effects include respiratory diseases (e.g., asthma, pneumonia, tuberculosis, lung function reduction, cardiovascular and eye diseases, pregnancy complications, Sick Building syndrome, Legionnaires' disease), heart diseases, or lung cancer. According to the 2009 U.S. Surgeon General's report (HHS, 2009), the identified strategies for a healthy home are facilitating a smoke-free environment, removing sources of Carbon Monoxide (CO), using depressurization systems to mitigate radon exposure, and control moisture at home to reduce allergens and sources of asthma.

While outdoor air quality has been extensively researched, not much had been done about indoor air quality even though we spend most of our life indoors (Sundell, 2004). Even corporate America understood the need for good hygiene within the home during the turn of the 20th century. Industrialists who ran company towns during the late 1800s and early 1900s sent so-called “sociologists” into homes to discuss the virtues of how a housewife should treat her husband and the home that he lives in while he is out working during the day. Some of these instructional tips conveyed during these consultations included proper dusting and house cleaning techniques to avoid build-up of dust and germs within the home (Wright, 1983).

A very comprehensive study about the history of indoor air was conducted by Sundell (2004), who documents that until the 1800s, breathing was believed to be a way of cooling the heart. It was Lavoisier (1743-1794) who discovered the role of oxygen in breathing in 1781. He found that the human metabolism involved the intake of oxygen and the release of Carbon Dioxide (CO_2), while he also found that the discomfort that we feel in crowded rooms was generated by Carbon Dioxide (CO_2). It was not until 1850, when the hygienic revolution started and when Pettenkofer (1818-1901) started to hold lectures on hygienic topics. One of the remarks that he made was that bad indoor air is not the main reason for illnesses, but it facilitates the human body to get weak. His view on Carbon Dioxide (CO_2) was also interesting in the sense that he thought that Carbon Dioxide (CO_2) is not important itself, but only useful as an indicator of the amount of other noxious substances produced by the human body.

Studies about ventilations started with the research by Elias Heyman (1829-1889), who experimented with different ventilation systems, including the measurement of Carbon Dioxide

(CO_2). He found that the amount of Carbon Dioxide (CO_2) was greater in schools without ventilation systems. However, he also commented that we could not rely on natural ventilation if we want clean air. Another scholar who extensively studied ventilation was Hermann Rietschel (1847-1914), who included guidelines on outdoor airflow requirements and created a scientific foundation for the widespread industrial application of heating and ventilation systems. Between 1880 and 1930, an extensive amount of studies investigated the toxic effects of organic substances in expired air. Many of them found no evidence of toxic effects related to high concentrations of Carbon Dioxide (CO_2) and hence, concluded that the heat and odor in crowded rooms is the primary reason for discomfort.

Up until the early 1930s, ventilation was studied in the realm of comfort, but not health. In those days, ventilation was considered as a technique to remove the odor or control the room temperature, but not the means to dilute moisture or dampness, or even remove pollutants. However, Winslow and Herrington (1936) found that the lack of ventilation can cause the loss of appetite for food due to substances in the air, and they found the same result in an experiment with heated dust from vacuum cleaners. Yaglou (1936) investigated the relationship between odor and ventilation by creating a psycho-physical scale for the subjective judgment of odor intensity, which is widely used even to this day. Yaglou (1936) found that recirculation of air did not affect the odor strength and that recirculation is only good for the distribution of air and the control of temperature, but in order to eliminate odor, it should be flushed away by clean air.

Sundell (2004) submits that, during the last century, indoor air quality and ventilation has not been the focus of health issues, but rather a subject of odor perception. However, a prominent and successful example that acknowledges indoor air quality as an important health concern can be monitored by the evolvement of the smoke-free policy in the United States. Hyland, Barnoya, and Corral (2012) document the history of smoke-free air policies and note that issues revolving around smoke has gone from the awareness of the health hazard of smoke to banning them from public places, and then to, educating and preventing youth from engaging in smoking habits. It is noted that now, the same strategy is applied to e-cigarettes.

In 1961, the American Lung Association wrote a letter to President John F. Kennedy to alert the evidence of the health hazards of smoking, which then was published in the 1964 report of the Surgeon General (Komaroff, 2014). Following this event, in 1975, the historic Minnesota Clean Indoor Air Act was signed into legislation, which banned smoking in most public workspaces (Brandt, 2007). In 1986, the 19^{th} Surgeon General's report on the consequences of involuntary smoking acknowledged and emphasized the hazardous effects of second-hand smoke.

One of the successful achievements of the American society in banning smoking in public indoor facilities was when the Congress prohibited smoking on domestic flights in 1987, which then took effect in 1989 (Brandt, 2007). Such a move was faced with strong opposition from the industry sector that tried to undermine the effects of smoking, and thereby delay the process of smoke-free policy implementations (Hyland, Barnoya, & Corral, 2012). This opposition was formed internationally and lead by the tobacco company Philip Morris. Firms tried to influence policymakers and diminish the hazards of smoking and its related effects at public and private indoor spaces by mainly blaming poor ventilation systems (Barnoya & Glantz, 2002, 2006).

Following up, in 1992, the U.S. Environmental Protection Agency published a report that asserted that second-hand smoking to be the reason for 3,000 lung cancer deaths of non-smoking people each year (U.S. Environmental Protection Agency (EPA), 1992). In response to a letter by the American Lung Association, in 1995, President Bill Clinton approved to let the U.S. Food and Drug Administration to monitor tobacco products. However, in 2000, the U.S. Supreme Court ruled in a 5-4 decision that the U.S. Food and Drug Administration should not have the authority over tobacco products without given the power of Congress. Yet, in 2009, President Barack Obama handed back the regulatory authority of tobacco control to the U.S. Food and Drug Administration, signaling that tobacco products are no longer exempt from rudimental oversight.

After the millennium, in 2006, the Surgeon General released a report that the 'debate is over' and 'the science is clear' that second-hand smoking causes lung cancer and heart diseases (HHS, 2006). As of 2014, The Affordable Care Act enacted health insurance requirements that must cover preventive services such as smoking cessation programs. The same legislative implementation was enforced by the Medicaid expansion, which benefited millions of low-income Americans to quit smoking. In the most recent years, in 2018, the U.S. Department of Housing and Urban Development (HUD) applied smoke-free policies in public housing units, which included not only the dwelling itself but also courtyards.

Mold

According to Jones (1999), indoor air quality is determined by multiple conjoint series of interactions that include indoor and outdoor interactions by microbiological, toxicological, and physical systems (i.e., building structure or attributes of a dwelling). Jones (1999) emphasizes that factors that determine the quality of the air within a containment are synergistically intertwined so that not a single factor alone would affect indoor air quality. Among the triggers that conjointly generate poor indoor air quality, mold and dampness (Bonner, Matte, Fagan, Andreopoulos, & Evans, 2006), tobacco smoke (Crain et al., 2002), furry pets, cockroaches, dust mites, rodents (Lanphear, Aligne, Auinger, Weitzman, & Byrd, 2001), and odorous chemicals (Tsai et al., 2006) have been found to trigger lung-related diseases.

Poor indoor air quality is also generated by outdoor pollutants entering the building (Grineksi, Collins, Chakraborty, & McDonald, 2013; Mendell, Mirer, Cheung, Tong, & Douwes, 2011). Previous literature document that indoor air quality is highly correlated with outdoor air conditions and that pollution particles observed outdoor are also observed indoor (Arku, Adamkiewicz, Vallarion, Spengler, & Levy, 2015), but at a lesser concentration (Patino & Siegel, 2018), and mostly they are linked to respiratory illnesses such as asthma.

In a study in Baotou, China, Bu, Wang, Weschler, Li, Sundell, and Zhang (2016) argue that the perception of odor or dryness would proxy poor indoor air quality. Among the surveyed indoor air components, moldy odor, tobacco smoke odor, or dry air showed a strong relationship with indoor air pollution while humid air was not. Also, homeowners reported much less odor perception than renters, while female survey respondents were more sensitive in detecting indoor air odor. Other than this finding in China, Huang et al. (2016) find evidence in metropolitan Shanghai that seasonal effects have a strong influence on children's respiratory health, especially in the winter season, when an increased amount of Carbon Dioxide (CO_2) was found.

Housing quality is a mediator towards health (Marquez, Francis, & Gerstenberger, 2019). Not only does it proxy a renter's financial constraints, but it also represents the renter's health because the quality of a dwelling and financial resources are directly related to a renter's well-being – especially for low-income families and those with disabilities (Marquez, Francis, & Gerstenberger, 2019). A study in the United Kingdom found that renters were four times more likely to experience damp situations at home than homeowners, as well as mental health issues such as depression and anxiety (Ellaway & Macintyre, 1998). Another study reported that renters were exposed to more hazardous environments such as dampness, noise, crime, and vandalism, rather than gardens or local amenities, which severely damaged their mental health (Macintyre et al., 2003).

Specific to mold, Cheple and Yust (1999) laid out indicators or symptoms of moisture: mold-in, water-in, frost-in, peeling paint, or ice dams. They investigated moisture problems in recently built homes in Minnesota and found that, despite the dissatisfaction and discomfort of moisture present in their homes, it was not a sufficient motivator to get the resident to move out. Pertinent to this result, the authors (Cheple & Yust, 1999) conclude that low education of residents also relates to health problems in moldy homes.

Not directly related to mold, yet another important venue in the environmental injustice literature can be found in floodplains and flood zones. In Miami, FL, Chakraborty, Collins, Montgomery, and Grineski (2014) found that when flood zones of different risk types were regressed on racial groups, the propensity of being a minority was higher in flood-prone areas. Collins, Grineski, and Chakraborty (2018) find a similar phenomenon in Houston, TX, where the socially vulnerable people lived in areas with higher flood risk, which also was occupied by toxic petrochemical industrial facilities.

Smoke

In terms of smoke and smoking behavior, one of the recent pieces of evidence pertinent to indoor air quality was found in public housing units in Boston, MA (Russo et al., 2015). Russo et al. (2015) compared Atmospheric Particulate Matter ($PM_{2.5}$) concentrations between smoke-free and smoke-permitted apartments. Atmospheric Particulate Matters ($PM_{2.5}$) are closely related to cigarette smoke, and their experiment found a significantly higher concentration of Atmospheric

Particulate Matters ($PM_{2.5}$) when there was a smoker in the household.[1] An interesting finding of this study was that even in smoke-free apartments with no smokers in the household, if a smoker's apartment was located nearby, the concentration of Atmospheric Particulate Matters ($PM_{2.5}$) increased. Arku, Adamkiewicz, Vallarion, Spengler, and Levy (2015) did further research on public housing units in Boston, MA, and found that tobacco smoke-related exposure also differed by season and building type.

Hewett, Sandell, Reece, and Bohac (2002) document that second-hand transfer smoke is prevalent among low-income households and renters. Around half of the survey respondents in their survey of renters in Minnesota expressed a discomfort from the smoke entering their apartment units, while only one-third of the renters in the sample were actual smokers. A similar study was provided by Laquatra, Maxwell, and Pierce (2002), who investigated the indoor air quality in nonmetropolitan counties in the State of New York. The authors (Laquatra, Maxwell, & Pierce, 2002) argue that a renter's tenure status puts them in situations with poor indoor air quality. This is supported by their finding of a negative relationship between income and radon exposure in a subsample of renters.

Regarding smoking policies throughout the country, in 1987, Aspen, CO, became the first city to mandate smoke-free restaurants. In 1998, the State of California became the first State in the nation to eliminate smoking in public places. This comprehensive law was the first statewide smoke-free air legislation in the nation and expanded the concept of public space by also defining bars and restaurants as public spaces (Barnoya & Glantz, 2004). Up until this day, this law is a landmark in American history in terms of improving indoor air quality. In 2002, the smoke-free

[1] $PM_{2.5}$ refers to Atmospheric Particulate Matter that have a diameter of less than 2.5 micrometers, which is about 3% the diameter of a human hair. Owing to their minute size, particles smaller than 2.5 micrometers can bypass the nose and throat and penetrate deep into the lungs and some may even enter the circulatory system.

law went into effect in the State of Delaware, which made Delaware the first State in four years to pass a smoke-free law. This was then followed by many other States in the 2000s, and, in 2012, the State of North Dakota became the 28th smoke-free State by passing a comprehensive smoke-free law.

2.2. Housing adjustment theory

The housing adjustment theory was first proposed by Morris and Winter (1975), and since then, it has formed the sociological backbone in housing research. Steggell et al. (2003) cite that the theory of housing adjustment has received the most consistent attention and testing of all the theories in housing research between 1989 and 1999. It assumes that a family would assess one's housing condition based on several norms, which then leads to a behavioral outcome (i.e., housing adjustment) of residential mobility, residential adaptation, or family adaptation. The primary reason for applying this theory in my study pertains to the compatibility of the constructs of this theory with the conceptual as well as the empirical model.

Very commonly, we can observe families moving from one area to the other or make amendments to adjust to the environment. Those are phenomena that are rooted in the housing adjustment theory, where residents make decisions based on the housing satisfaction level that is generated by cultural norms, current living conditions, or expectations and preferences of the family.

The notion of cultural norms relates to the living pattern or housing needs differing by families and is pertinent to the concept of physical shelter, tenure, quality, or neighborhood. Morris and Winter (1975) explicitly mention that a cultural norm, or in other words, housing needs derive from "minimum shelter needs or minimum health and safety standards in any absolute sense" (p.

82). One of the strongest American housing norms, according to Morris and Winter (1975), is the need for adequate living space (e.g., squared footage). It literally can be the different expectations of proper housing by different cultural backgrounds, but it also can be individual expectations of a family. For example, the ideal of a good physical location of a dwelling in Asian culture is heavily influenced by Feng Shui (Xu, 2012), which cites that a dwelling is warmer in the winter when the windows are facing south. This cultural norm facilitates putting a premium in the house price in the real estate market when a dwelling is facing south (Lu, 2018). An example of the second type of cultural norm can be a family's preference to live in a dwelling with good indoor air quality, a trait that has not normally been addressed within the Morris and Winter (1975) model. Such a preference is considerably, a singular family's need that incorporates a family's health standard. This is because every family assesses the indoor air quality of a dwelling differently. Pertinent to the health concerns of a family, Morris and Winter (1975) do also include minimum health standards in a dwelling as a cultural norm that is fundamental to a family's well-being.

Morris and Winter (1975) submit that during a life course, families make decisions about their lives pertinent to housing, where they evaluate their cultural standards against the dwelling condition and, if dissatisfied, would make a decision to move or adapt. The decision that is made from the discrepancy in preferences and the environment (i.e., cultural norms (housing needs) and living conditions) would result in three behavioral outcomes: residential mobility, residential adaptation, or family adaptation. Examples of residential mobility would include behaviors that would require long-distance moves due to economic opportunities, and short-distance moves motivated by a single labor or housing market. Residential adaptation refers to activities altering or modifying the dwelling to fit the family's needs. Remodeling or alterations of the rooms, kitchen, or bathrooms can be included in this kind of behavior. Family adaptation is a behavior where the family adjusts to the norm and living conditions. Examples would include reorganizing or disintegrating the household or social actions such as divorce. These three behavioral responses require decision making based on the gap between the expectation derived from the housing norm and its actual condition. If the housing condition is not meeting the norms, this deficit or dissatisfaction will pressure the family to adjust its housing condition by these three behavioral patterns.

Norms of housing

The behavioral motivation of the housing adjustment theory is that people put effort into earning respect from others and oneself (Steggell et al., 2003). Framed in the context of one's housing condition, one would make decisions whether the dwelling and its entailed amenities are proper based on multiple facets and dimensions, which we define as cultural norms.

The core of this theory resides in a decision-making process regarding matters of housing. A decision is derived by multiple steps of assessments on one's current housing condition. An important aspect that the housing adjustment theory requires is a systematic structure that determines the decision outputs. Morris and Winter (1975) argue that the housing adjustment theory requires a systematic decision-making mechanism in order to obtain an optimal output, which is based on multiple steps of decision-making processes. The standards or the criteria on which the residents make decisions are called norms, and, as elaborated before, it is heavily grounded on cultural norms, and if the reality is not meeting those standards, the dwelling occupant accordingly takes actions. It is my belief that adequate indoor air quality represents one of these types of housing norms captured within the housing adjustment theory.

The terminology norm in the housing adjustment theory refers to a common cultural code that people share within the same culture. According to Morris and Winter (1975), the American housing norm (the cultural norm in housing) consists of five constructs. Those are space norm (e.g., number of rooms and bedrooms), tenure norm (e.g., homeownership, renter status), structure type norm (e.g., single-family home, multi-family home, condominiums), quality norm (e.g., indoor air quality), and neighborhood norm (e.g., safe neighborhood).

Pertinent to the tenure status of being a low-income renter, Skobba, Bruin, and Carswell (2013) compare the normative housing deficits before and after one obtains a housing voucher. The authors (Skobba, Bruin, & Carswell, 2013) find that low-income working people used housing vouchers to overcome the housing deficits that contradicted their norms. Thus, housing vouchers lowered the propensity to move and overcome the discrepancy between expectation and realization of one's dwelling. The authors (Skobba, Bruin, & Carswell, 2013) also find that the norms of the low-income population are not different from a higher income group, which verifies that housing norms are universal concepts applied to housing regardless of the level of income. Another qualitative result that this study found is that residents made trade-offs in assessing the housing condition with these norms. This means, renters do have a priority in norms, whereby Skobba, Bruin, and Carswell (2013) found that the location of the home was at the top of their list.

Within the frame of environmental injustice and the status of a renter, the Harvard Joint Center for Housing Studies (JCHS, 2019) documents that the construction industry has been booming with greater housing construction and a lower vacancy rate of rental units.[2] However, this growth of the housing market was primarily targeting the higher end of the income spectrum. This is because the cost of material and labor to construct dwellings have been on an ongoing rise

[2] Such a boom in the housing market has been unprecedented since 1974.

so that construction for the lower middle class, as well as low-income people, was not profitable (JCHS, 2018). Accordingly, the tight supply of rental homes for the poor left them to live in dwellings with dilapidated conditions.

It has been recorded that, in the case when renters were undocumented immigrants, the housing condition did not improve at all in the southern part of Phoenix, AZ (Grineski & Hernandez, 2010). Being undocumented, tenants were helpless to make a claim against the landlord out of the fear of eviction and deportation. This vicious cycle of poverty, fear of deportation, and deterioration of health repeated in the neighborhood. Important to note is here that, in many datasets, contrary to the Black population, the Latin population records a low number of hospitalizations and thereby record a low number of health problems in the data. This is because those without documentation heavily rely on healthcare services provided by schools rather than visiting hospitals (Grineski, 2008).

Memken and Canabal (1994) find that being a minority has a strong relationship with living in a lower quality dwelling. The authors (Memken & Canabal, 1994) find inference in the housing market discrimination (see also, Northridge, Stover, Rosenthal, & Sherard, 2003). That is, lower-income people do not get equal treatment in the housing market so that their path towards housing is only granted by living in substandard dwellings.

Another study on vulnerable populations was conducted by Cook, Bruin, and Winter (1994), who did research on the most determinant factors of housing cost burdens of female residents. By investigating the cost burdens of five different female groups (female-headed households: single mothers, older women living alone, nonelderly women living alone, older women living with others, and nonelderly women living with others), the authors (Cook, Bruin, & Winter, 1994) find that education level, household size, tenure, age of the house, mobile home residence, and government assistance were important predictors of the housing cost burden of a female householder.

Intervention and residential adaptation

This subsection about the literature on intervention efforts relates to the notion of housing decisions found using the housing adjustment theory. According to the housing adjustment theory, residents assess their housing conditions based on an individual as well as a common cultural norm. In the framework of this study, such conditions would correspond to the exogenous variables in the model whereby the health outcome pertinent to indoor air quality would be the cultural norm that is going to be assessed by the dwelling occupant. If the occupant finds that the condition is not meeting one's expectations, the residents would be dissatisfied and accordingly would take actions. Morris and Winter (1975) describe three types of behavioral responses to a dissatisfied assessment. Those are residential mobility, residential adaptation, and family adaptation. Among these three, the behavioral outcome that corresponds to this study is the residential adaptation of the dwelling occupant. As it will be shown later in the empirical model, I included a variable that proxied the intervention or maintenance effort of the resident. This variable corresponds to the behavioral concept of residential adaptation in the original work of Morris and Winter (1975).

Intervention for the improvement of air quality can be tricky. According to Sexton and Repetto (1982), the reason for that is based on the fact that air and air quality is a public good. Since it is a public good, it is very unlikely that a rational individual would undertake the necessary actions to prevent or keep the air clean for others. The reason why an individual hardly would invest in a public good is because the cost of public air would exceed one's benefit from clean air. In other words, while indoor air should be taken care of the dwelling occupant, the outdoor or public indoor air condition would need to be regulated by public authorities because, in such places, the cost of maintaining a clean air environment would exceed the budget of an individual.

Within the framework of indoor air quality and the types of behavioral response discussed in the housing adjustment theory, Russo et al. (2015) emphasized the role of smoke-free building policies. Russo and her co-authors acknowledge that there is a significant difference in the presence of smoke in the housing unit when comparing a housing complex with a smoke-free policy and units where smoking is partially permitted. Russo et al. (2015) find that allowing smoking in designated areas continued to have transfer smoke to non-smoking units. The authors (Russo et al., 2015) argue that in order to reduce the peril of second-hand smoking, housing management should entirely eradicate the source. Furthermore, Teach, Crain, Quint, Hyland, and Joseph (2006) report that places that are exposed to environmental tobacco smoke were also likely to have cockroaches and mold. In most cases, environmental tobacco smoke (ETS) was often considered as the key element of poor indoor air quality. However, contrary to these findings, there are also opposite findings. Holcomb (1993) summarized public health releases of the 1980s and estimated the portion of various components produced by ETS. His result showed that ETS has only a minor impact on indoor air quality.

Regarding the strategy of education as a means for intervention, Keall, Baker, and Howden-Chapman (2010) argue that an assessment of a dwelling should be comprehensive in the sense that one should assess not only the dwelling itself but also the occupant’s behavior and its surrounding neighborhood. For example, the authors (Keall, Baker, & Howden-Chapman, 2010) found that even dwellings with good ventilation would be exposed to mold if the resident is uneducated about ventilation while cooking or bathing. In other words, without the knowledge and management of prevention on the triggers of poor indoor air quality, prevention would not be effective. Behaviors can be changed through education and interventions. The importance of knowledge is shown by Johnson, Cole, and Merrill (2009), who conducted a survey on college students living off-campus of Brigham Young University. In their sample, college students were predominantly renters, whereby higher rent was not aligned with fewer housing problems. Also, around 79 percent of the college students lived in apartments, and females were significantly more likely to report health problems.

Pertinent to the benefits of intervention, Beko, Clausen, and Weschler (2008) find that the benefit of replacing an air filter exceeds the long-term economic cost associated with an occupant's productivity. Fabian, Adamkiewicz, Stout, Sandel, and Levy (2014) simulated with asthma data of low-income multifamily housing units and found that the cost of intervention such as pest control or exhausting fans would offset the cost of healthcare. Furthermore, Boatman (1994) observed that technological advancement to keep up with indoor air quality-related regulations made a piece of equipment cheaper and more energy-efficient.[3]

Improvement of the dwelling condition is considered as one of the means of intervention. In an archival study on housing-based interventions between 1990 and 2001, Saegert, Klitzman, Freudenberg, Cooperman-Mroczek, and Nassar (2003) document that most of the intervention strategies in the past were pursued by educating the residents and making environmental improvements. The objective of those interventions mostly aimed to achieve a change in the resident's knowledge, attitude, or behavior regarding healthy housing, which was then followed by an actual improvement of the dwelling.

In Seattle, WA, Krieger, Takaro, Song, and Weaver (2005) applied an intervention strategy with community health workers on 274 low-income households with children from four to twelve

[3] The Occupational Safety and Health Administration (OSHA) first proposed the indoor air quality regulations in 1994. Since then, it took two years to revise and set the standards.

with asthma. Community health workers facilitated education and behavioral changes in reducing the exposure of indoor air asthma triggers. The result showed an improvement by a greater intensity of interventions. This result also supports Spetic, Kozak, and Cohen's (2008) finding who use a sample of Canadian residents who were questioned about their knowledge and awareness of indoor air quality and energy efficiency. By means of cluster analysis, the authors (Spetic, Kozak, & Cohen, 2008) found that less mold was found in the participants' units when they were more aware of the humidity level of their dwellings.

Level of analysis

According to the United Nations Habitat Agenda, housing is defined as a broad concept that incorporates physical shelter and the community. To be more specific, Jacobs (2011, p.115) defines housing as "adequate privacy; adequate space; physical accessibility; structural stability and durability; adequate lighting, heating, and ventilation; adequate basic infrastructure such as water supply, sanitation, and waste management facilities; suitable environmental quality and health-related factors; and adequate and accessible location with regard to work and basic facilities."

Evans and Kantrowitz (2002) document that housing quality is tied to income. The authors (Evans & Kantrowitz, 2002) argue that there is an inverse relationship between income and the necessary maintenance in a dwelling and that people from low socioeconomic statuses suffer from inadequate housing amenities such as incomplete bathrooms, absence of a sewer or central heat system, holes in the floor, open cracks, or leaky roofs. Evans and Kantrowitz (2002) explained that inequality has several dimensions, such as air and water pollution, noise, residential crowding, housing quality, educational facility, work environment, and neighborhood quality. It is my belief that the housing quality dimension can be combined with indoor air quality to point out further inequalities.

Pertinent to urban environments, Harlan et al. (2008), and Sadd et al. (2011) argue that the urban environment can be stratified into race, ethnicity, and income. Several studies have found that the ground heat in urban areas is higher (Mitchell & Chakraborty, 2014) and has greater exposure to environmental hazards (e.g., Stewart, Bacon, & Burke, 2014). Similarly, Evans and Kantrowitz (2002) submit that ten percent of the low-income households with income below the poverty line primarily reside in hot air units without ducts, while ten percent relied on unvented gas heaters as a primary heat source. Also, about fifty percent of low-income people with asthma problems came from inner-city urban areas and showed complex positive reactions to cockroaches (Kang, 1976).

One of the most heavily researched illnesses in urban settings is asthma. In terms of respiratory problems, previous literature has done research on bronchitis, emphysema, and asthma, yet the majority of studies are asthma-related studies (e.g., Carson & Stroebel, 2001; Jones, Lawson, Robson, Buchnanan, & Aldich, 2004). Many studies have been documenting that African Americans have a higher rate of asthma hospitalization (e.g., Boudreaux, Emond, Clark, & Cainargo, 2003; Aligne, Auinger, Byrd, & Weitzman, 2000). Grineski (2007) explored the Phoenix, AZ area, and found that African Americans have more indoor hazards and neighborhood toxic air releases so that they presented a greater propensity towards asthma hospitalization per Zip code area. This finding can also be contributed to the fact that many African Americans do not have access to proper healthcare and therefore record a high number of emergency room visits (Brown et al., 2012).

Rauh, Landrigan, and Claudio (2008) laid out a mediation framework on how pollutants mediate one's socioeconomic status towards health and is a similar mediation model used in this study. A modified version of the original conceptual model in Rauh, Landrigan, and Claudio's (2008) study is attached in the appendix. The major three components in these authors' (Rauh, Landrigan, & Claudio, 2008) conceptual model were socioeconomic status, housing condition, and health output. These three major components constitute the main mediation model, while they can be evaluated by three different social hierarchal layers. Noted is that Rauh, Landrigan, and Claudio (2008) did not apply any empirical analyses in their study, which defines their study as being merely conceptual.

As aforementioned, Rauh, Landrigan, and Claudio (2008) decomposed their conceptual mediation model into levels of analyses (i.e., social-hierarchal dimensions). The most macro-level analysis is the metropolitan city-level analysis and is the primary unit to evaluate citywide policy implications. The second level is the neighborhood and community level analysis, which investigates ethnic compositions and human capital, such as the education level of a neighborhood. The third and most micro level of analysis explores at the individual and family level and relates to characteristics of a family's livelihood.

As for the housing condition, Rauh, Landrigan, and Claudio (2008) suggest several variables corresponding to each social dimension. The variables that I used in this study correspond to the neighborhood/community and individual/family level analysis. For example, I used variables such as the annual maintenance cost of the homeowner or the age of a dwelling that are variables at the neighborhood and community level. I also used variables such as the square footage of a dwelling, which is a housing variable at the individual and family level. While the authors were not specific in explaining why the age of a dwelling is categorized as a neighborhood or community level variable, it can be assumed that dwellings in an urban neighborhood are similar in age due to the development pattern in urban areas. To be more specific, many neighborhoods have dwellings that are similar in age, quality, and structure so that these variables would sufficiently proxy the attribute of a neighborhood. However, this argument can be opposed by whether it would make a difference when the housing stock in the neighborhood is homogenous. In other words, it can be argued whether there is, in fact, a difference at the neighborhood level when all dwellings are the same. This argument can be disputed in the sense that, while the housing stock 'within' the neighborhood might not differ much, the housing stock 'between' neighborhoods would differ based on a neighborhood's income level. Thus, when comparing the housing condition 'between' neighborhoods, one would simultaneously proxy the income as well as the environmental well-being of its residents.

The outcome variable of the mediation model in this study, as well as the one suggested by Rauh, Landrigan, and Claudio (2008), has three social-hierarchal levels as well. If the health outcome is about racial, ethnic, or socioeconomic disparities, Rauh, Landrigan, and Claudio (2008) suggest that it should be categorized at the social and structural level of environmental injustice. An outcome at a smaller level, such as a census tract, Zipcode area, or housing unit, is a neighborhood or community level health disparity outcome, while an individual specific health outcome would be analyzed at the individual or family level.

CHAPTER 3

EMPIRICAL ANALYSIS

3.1. American Housing Survey

This study uses the 2011 American Housing Survey (AHS), a public dataset administered by the Census Bureau and the U.S. Department of Housing and Urban Development (HUD). This biennial public dataset is one of the most comprehensive housing surveys in the nation and contains physical conditions of housing units, neighborhood quality, demographic information of its residents, and home maintenance activities. The primary reason why I used the 2011 version heavily relates to the presence of the variable that I needed for this research. Only in the 2011 version, we have the variables related to mold, smoke, and health condition of the household head altogether, while in other versions, they were not provided in the same survey year. In this study, these data were truncated by only metropolitan areas. This would include households in the primary central city of the metropolitan statistical area (MSA), the central city of the MSA, inside the MSA, but not in the central city and yet urban; and outside the MSA area and still designated as being urban. According to the American Housing Survey, these areas are defined as urban locations. The primary reason for restricting the sample to only urban dwellers comes from the fact that many minorities are living in an urban environment (Harlan et al., 2008; Sadd et al., 2011) and have greater exposure to environmental hazards (e.g., Stewart, Bacon, & Burke, 2014). On top of this truncation, I also restricted this dataset by only renters and homeowners, and this truncation resulted in 35,730 observations of renters and 57,919 observations of homeowners. That is, 38.1

percent represented urban dwellers who were renters and 61.9 percent, homeowners.[4] Pertinent to the use of the 2011 data, that is a little outdated compared to the most recent 2017 version, my argument is that the fundamental relationship between a resident's socioeconomic status and the mediating effect of mold and smoke toward a negative health condition would not change even in the future. Thus, since this study explores a fundamental causal inference rather than a historically changing relationship between one's social status, health, and indoor air quality, the use of the 2011 dataset was optimal.

[4] An exploratory analysis on the type of the urban homeowners and renters' dwellings was obtained by the variable TYPE. The tabulation result by homeowner and renter showed that about 96.12 percent of the homeowners and 97.95 percent of the renters were living in dwellings such as house, apartment, or flat. Unfortunately, the 2011 American Housing Survey (AHS) was not specific about the distribution among those three types.

Table 1. Summary statistics of the homeowner and renter

	HOWNER					RENTER				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max	N	mean	sd	min	max
HLTH_EXVG	57,919	0.851	0.356	0	1	35,730	0.790	0.407	0	1
WHITE	57,919	0.850	0.357	0	1	35,730	0.718	0.450	0	1
BLACK	57,919	0.0873	0.282	0	1	35,730	0.198	0.398	0	1
LATIN	57,919	0.00418	0.0645	0	1	35,730	0.0107	0.103	0	1
HSCHOOL	57,919	0.453	0.498	0	1	35,730	0.617	0.486	0	1
LOWINC	57,919	0.364	0.481	0	1	35,730	0.735	0.441	0	1
HHAGE	57,919	53.94	15.33	15	93	35,730	43.43	17.02	14	93
MOLD	57,919	0.146	0.353	0	1	35,730	0.188	0.391	0	1
SMOKE	57,919	0.193	0.395	0	1	35,730	0.338	0.473	0	1
UNITSF	57,919	2,289	1,951	99	20,159	35,730	1,123	1,093	99	20,159
AGEHOUSE	57,919	40.15	25.49	0	92	35,730	44.64	24.61	0	92
CSTMNT	57,919	804.4	1,160	0	6,034					
MNTNS						35,730	0.807	0.395	0	1

Note. This is a subsample of homeowners and renters. The total observation number of homeowners is 57,919 and 35,730 in the renter's sample. Regarding the variables, HLTH_EXVG is a binary variable, indicating whether the household head has self-reported an excellent or very good health status. Race-related variables were WHITE, BLACK, and LATIN, each indicating three racial groups in the United States: European, African, and Latin Americans. My sample truncated the sample into four race groups, including Asians, which is not used in the analysis. However, for example, a comparison of WHITE would compare WHITE against Asians as a baseline comparison group. HSCHOOL is a binary variable that indicates whether the respondent was a high school graduate or less. A comparison against HSCHOOL would compare this group with all other educational strata (i.e., education higher than a high school diploma). LOWINC is an indicator variable for low-income people. The threshold to qualify as a low-income population was based on the maximum low-income limit threshold set by the Department of Housing and Urban Development (HUD). An income level lower than this threshold was categorized as LOWINC. HHAGE is the age of the household head. As elaborated before, the American Housing Survey acknowledges the first respondent in a household as the household head. The variable MOLD was generated by combining observations of mold in the household in any place of the dwelling or when the resident had smelled a musty smell from a few times to a daily basis. SMOKE is an indicator variable that captures whether the resident has smelled smoke entering the dwelling at least a few times up to a daily basis or when there was a member or visitor who was a smoker, as well as whether the resident had exposure to second-hand smoking. UNITSF is the square footage of the dwelling and was used as a logged value in the regression and mediation models. The same conversion was applied to AGEHOUSE, which is the age of the house from the standpoint of the year 2011. CSTMNT is a variable that is only used in the homeowner's sample and is the annual cost of maintenance that the homeowner has spent. This variable is specifically pertinent to the homeowner because, in the original American Housing Survey (AHS), no values were observed when the survey respondent was a renter. Like the two previous variables, also this variable was used in a logged form. MNTNS is a variable that is only used in the renter's sample and indicates whether the renter was completely or partly satisfied with the maintenance in the dwelling. MNTNS is a renter specific variable in the sense that there were no observations of this variable in the homeowner's sample.

As it is shown in the summary statistics of the main dataset that was used for the full models, most of the variables were dichotomous variables that were either coded one or zero. Regarding the health status of the survey sample, I generated the variable HLTH_EXVG, which is a binary variable of the household head who has self-reported an excellent or very good health status and was used as the dependent variable in the regression and mediation analyses. Here, it is noted that the American Housing Survey (AHS) considers a household head as the person who first responded to the survey regardless of who the actual household head among the spouses is. The HLTH_EXVG variable was extracted from the survey question that marked the survey respondent's self-reported health status from poor to excellent, whereby only an "excellent" and "very good" health status was incorporated as HLTH_EXVG. The primary reason for extracting the healthiest outcomes is twofold: First, since this variable is a self-reported variable, there was a suspicion of ambiguity on the discrepancy of the actual and reported health condition of the respondent. Other than when the respondent was at the extreme end of the positive or negative health spectrum, reports such as a fair condition showed an ambiguous result. Second, rather than using the extreme negative poor health report, it was better to use the positive side of the health reports to make the model more comprehensive to the reader in the sense a negatively deteriorating health condition would correspond to a negative sign in a regression framework. In general, homeowners showed a higher percentage of healthy residents than renters, while the spread was greater in the renter's sample.

In terms of the race and ethnicity related variables, WHITE, BLACK, and LATIN, indicate three groups in the United States: European, African, and Latin Americans. The sample truncated the sample into four race groups, including Asians, which is not used in the analysis. However, for example, a comparison of WHITE would compare WHITE against Asians as a baseline comparison group, which was the healthiest racial/ethnic group in the dataset. A comparison with the healthiest group would enable us to compare better the health deterioration of the racial as well as ethnic groups in the sample. It has been recorded that health-related outcomes of Latin populations are somehow ambiguous in the sense that many of them are at an illegal status so that they avoid using hospitals (Grineski & Hernandez, 2010). Due to this phenomenon, the health outcome of the Hispanic population in many datasets show an extremely healthy status. In order to screen out this bias, I stringently screened the data with no racial overlaps. That is, each observation in my sample should have belonged to one of the three racial groups, and exceptional cases were dropped. This procedure diluted the health outcome bias in the American Housing Survey data. Regarding the results in the summary statistics, the majority of homeowners and renters were White.

Alongside the race variables, also education, income, and age-related variables were included in the models. HSCHOOL is a binary variable that indicates whether the respondent was a high school graduate or less. A comparison against HSCHOOL would compare this group with all other educational strata (i.e., education higher than a high school diploma). The reason for setting the education level variable at the lower bound was because it was found that low-educated residents were not motivated enough to move out of moldy residents (Cheple & Yust, 1999). By the same token, an indicator variable for the low-income population was included. LOWINC is an indicator variable for low-income people. The threshold to qualify as a low-income population was based on the maximum low-income limit threshold by county set by the Department of Housing and Urban Development (HUD). An income level lower than this threshold was categorized as LOWINC. HHAGE is the age of the household head. Regarding the summary statistics, renters were, in general, lower educated and earned less, while homeowners were, on average older than renters. Pertinent to the health attributes by age, most of the homeowners, as well as the renters reported an excellent or very good health condition: Around 85.1 percent of the homeowners and 79 percent of the renters reported this result.

The proxies for poor indoor air quality are MOLD and SMOKE. This is because mold and dampness (Bonner, Matte, Fagan, Andreopoulos, & Evans, 2006) or tobacco smoke (Crain et al., 2002) conjointly generate poor indoor air quality. Thus, indoor air quality is not an issue of a single factor alone (Jones, 1999). The variable MOLD was generated by combining observations of mold in the household in any place of the dwelling or when the resident had smelled a musty smell (i.e., the variable MUST in the American Housing Survey (AHS)) from a few times to a daily basis. SMOKE is an indicator variable that captures whether the resident has smelled smoke entering the dwelling at least a few times up to a daily basis or when there was a member or visitor who was a smoker, as well as whether the resident had exposure to second-hand smoking. Regarding the values in the summary statistics, a greater percentage of mold and smoke was observed in the renter's home, while the discrepancy between homeowners and renters was greater for SMOKE.

This study also included variables related to the physical condition of the dwelling. The square footage of the dwelling UNITSF was used as a logged value in the regression and mediation models. The same conversion was applied to AGEHOUSE, which is the age of the house from the standpoint of the year 2011. This variable was generated by subtracting the values of the variable BUILT (i.e., the year when the dwelling was built) from the year 2011. The UNITSF variable did not need to add a value of one when converting it into a logarithm because the minimum value of UNITSF was 99 square footage, while there were homes built in 2011 so that AGEHOUSE had observations with values of zero. As for the lnAGEHOUSE variable, since a logarithm of zero does not exist, I added one year to each AGEHOUSE and then took the logarithm. The same treatment was applied to the CSTMNT variable, which is the annual cost of maintenance that the homeowner has spent. This variable was only observable in the homeowner's sample and proxied the intervention effort of the homeowner to improve the living condition of the dwelling. The same type of variable was used in the renter's sample. MNTNS is a variable that is only used in the renter's sample and indicates whether the renter was completely or partly satisfied with the maintenance in the dwelling. MNTNS is a renter specific variable in the sense that there were no observations of this variable in the homeowner's sample. Regarding values listed in the summary statistics, on average, homeowners occupied a larger dwelling whereby the spread of the home sizes was almost similar among homeowners and renters. The age of the house variable showed the same pattern. While the spread of the age of the homes was nearly identical between homeowners and renters, on average, homeowners occupied a slightly newer home. The CSTMNT showed a skewed pattern in the sense that the standard deviation was greater than the average cost of maintenance, while the maximum amount was departed far away from the mean expenditure. As for renters, around 80 percent were satisfied with the maintenance service that was provided by the landlord.

As for concerns about whether there were any overlaps between the homeowner and renter samples, I examined them by tabulating the homeowner and renter samples when they were combined in one dataset, and it showed that they were indeed entirely separate datasets. This bolsters the argument that the summary statistics of HHAGE, UNITSF, and AGEHOUSE come from different survey respondents. At a glance, these variables have the similar or same minimum and maximum values. However, they still have different mean and standard deviations, which supports the fact that they are indeed different subsamples.

3.2. Structural equation model

From a systems framework, my structural equation model (SEM) was built based on the input of exogenous variables that pass through the endogenously generated mediator variables (MOLD and SMOKE) and lead to the endogenous outcome variable (HLTH_EXVG). In this system, I argue that MOLD, SMOKE, and HLTH_EXVG are not exogenously given, but endogenously generated by the homeowner or renter's status and living condition.

The structural equation model (SEM) in this study was based on a maximum-likelihood estimation while the errors were clustered at the state-county level. I do not assume any latent variables that are frequently used when incorporating a factor analysis in the model. Thus, all the variables in my model were observed variables. While the traditional Sobel (1982, 1986) method estimates a mediation effect by an Ordinary Least Square (OLS) regression, my structural equation path analysis relies on a maximum likelihood estimation that fits the data to a Binominal distribution because the dependent variable is binary. To be more specific, as it is shown in Figures 1 and 2, as well as Table 2, the dependent variables are MOLD, SMOKE, and HLTH_EXVG that hold all the exogenous variables in their models that have a connection with them. That is, rather than individually estimating each path, the structural equation model estimates all the exogenous variables together in a model. This is also the reason why the model fit of a structural equation model should be presented in terms of the sum of the R-squared results of all the estimations.

There are two weaknesses in the Sobel method (1982, 1986). The first fallacy of the Sobel method (1982, 1986) comes from the assumption that each individual regression of the paths would together generate a combined Normal distribution. While in most cases, a combination of a different distribution with a Normal would generate a Normal distribution, this is not always the case when the other distribution that is combined with a Normal distribution dominates. In order to overcome this issue, Hayes (2013) bootstraps the residuals based on a Normal distribution, and his approach is a more refined approach than the original method proposed by Sobel (1982, 1986).

The second weakness of the Sobel method (1982, 1986) is (as well as Hayes' (2013) approach) since it estimates by an Ordinary Least Square (OLS) regression, it would result in a Linear Probability Model (LPM) if the dependent variable is binary. This would not be a problem when the fitted line is plotted on a space where all the predicted values of the dependent variable are positive. Yet it would cause serious issues when the predicted line passes through negative dependent variable values. Because a binary variable only contains zero or one values, predicted values that are negative would be counterintuitive. Such a problem is overcome when using the structural equation method because it fits the dependent variable of all kinds of nature to its corresponding distribution.

In my model, I correlated MOLD and SMOKE. The prominent reason for that is because it was documented that mold and smoke jointly generate poor indoor air quality (Bonner, Matte, Fagan, Andreopoulos, & Evans, 2006; Crain et al., 2002). The relationship between MOLD and SMOKE in both samples is highly significant, as shown in Figures 1 and 2. The correlation between MOLD and SMOKE in the homeowner's sample was 0.013 and in the renter's sample, 0.019, which shows that the conjoint effect of MOLD and SMOKE is larger in the renter's dwelling. Based on this close relationship between MOLD and SMOKE, as it is shown in Table 2 (Models 1, 2, 4, and 5), ε_1 and ε_2 were correlated to each other and the coefficients were weighted like in a Seemingly Unrelated Regression (SURE) (i.e., the Kronecker product of ε_1 and ε_2), while clustering the variance-covariance matrix by 77 counties. That is, the variance-covariance matrices of the error terms ε_1 and ε_2 were multiplied by a Kronecker product, stratified into 77 counties, and then used to weight each coefficient. This would mean that Models 1 and 2, as well as, Models

4 and 5 would have originated from the same combined error term (i.e., the result of the Kronecker product) by homeowner or renter, whereby the differences in the standard errors of each coefficient was coming from different variables, values, and observations present in each county.

Pertinent to the interpretation of the coefficients, as elaborated in the previous paragraphs, the direct effects are obtained from the estimations in Table 2 where I estimated all the exogenous variables based on three dependent variables (i.e., MOLD, SMOKE, and HLTH_EXVG) that are endogenous to the exogenous variables (i.e., the independent variables in Table 2). The interpretation of the effect sizes of the direct effects is straightforward from reading off the estimation results, but obtaining the indirect effect requires extra computation. The indirect effect is the multiplication of paths that lead to and go out from the mediator. Since I interrelated MOLD and SMOKE, it would make more sense when the aggregated indirect effects through both MOLD and SMOKE is computed.

$$\begin{aligned}\text{Aggregate Indirect Effect of Exogenous Variable}^{\text{h,r}} \\ &= \{\beta_{(\text{Exogenous Variable}\rightarrow\text{MOLD})} * \beta_{(\text{MOLD}\rightarrow\text{HLTH})}\} \\ &+ \{\beta_{(\text{Exogenous Variable}\rightarrow\text{SMOKE})} * \beta_{(\text{SMOKE}\rightarrow\text{HLTH})}\}\end{aligned}$$

As shown in the equation above, the aggregate indirect effect is the sum of the two indirect effects that were passing through MOLD and SMOKE. The superscripts h and r are indicators of homeowner and renter each related to the samples used to compare the effect sizes. Here, $\beta_{(\text{Exogenous Variable}\rightarrow\text{MOLD})}$ is the estimated direct effect coefficient (see Figures 1, 2, and Table 2) in the path model going from the exogenous variable towards MOLD. By the same token, $\beta_{(\text{Exogenous Variable}\rightarrow\text{SMOKE})}$ is the direct effect from the exogenous variables towards SMOKE.

The paths that are going from either MOLD or SMOKE towards HLTH_EXVG are $\beta_{(\text{MOLD}\rightarrow\text{HEALTH})}$ and $\beta_{(\text{SMOKE}\rightarrow\text{HEALTH})}$. The sum of the multiplications that pass via MOLD and SMOKE is the aggregate indirect effect through both MOLD and SMOKE, towards HLTH_EXVG. The aggregate indirect effect is evaluated by the *Z*-statistics, where this multiplicative is divided by their standard errors.

The total effect is the sum of the direct effect from the exogenous variable directly going to the health variable HLTH_EXVG, added by the aggregate indirect effect. The equation to obtain the total effect of an exogenous variable is shown below. The direct effect from the exogenous variable towards the health variable can be found in Figures 1, 2, or Table 2. It is basically the estimation result of the exogenous variables in Models 3 and 6, where the dependent variable is HLTH_EXVG. The direct effects leading towards MOLD or SMOKE are the coefficients reported in Models 1, 2, 4, and 5 in Table 2. Like the direct and indirect effects, also this effect is evaluated by the *Z*-statistics and assesses whether the total effect size is significantly different from zero.

$$
\begin{aligned}
&\text{Total Effect of Exogenous Variable}^{h,r} \\
&\quad = \text{Direct Effect from Exogenous Variable}^{h,r} \text{ towards Health Variable}^{h,r} \\
&\quad + \text{Aggregate Indirect Effect of Exogenous Variable}^{h,r} \\
&\quad = \beta_{(\text{Exogenous Variable}\rightarrow\text{HLTH})} + \left\{\beta_{(\text{Exogenous Variable}\rightarrow\text{MOLD})} * \beta_{(\text{MOLD}\rightarrow\text{HLTH})}\right\} \\
&\quad + \left\{\beta_{(\text{Exogenous Variable}\rightarrow\text{SMOKE})} * \beta_{(\text{SMOKE}\rightarrow\text{HLTH})}\right\}
\end{aligned}
$$

The interpretation of the equation above is simply the sum of the coefficient of the direct effect from the exogenous variable to the health variable (i.e., $\beta_{(\text{Exogenous Variable}\rightarrow\text{HLTH})}$), added by the sum of the indirect effects through MOLD (i.e., $\beta_{(\text{Exogenous Variable} \rightarrow \text{MOLD})} * \beta_{(\text{MOLD} \rightarrow \text{HLTH})}$) and SMOKE (i.e., $\beta_{(\text{Exogenous Variable} \rightarrow \text{SMOKE})} * \beta_{(\text{SMOKE} \rightarrow \text{HLTH})}$).

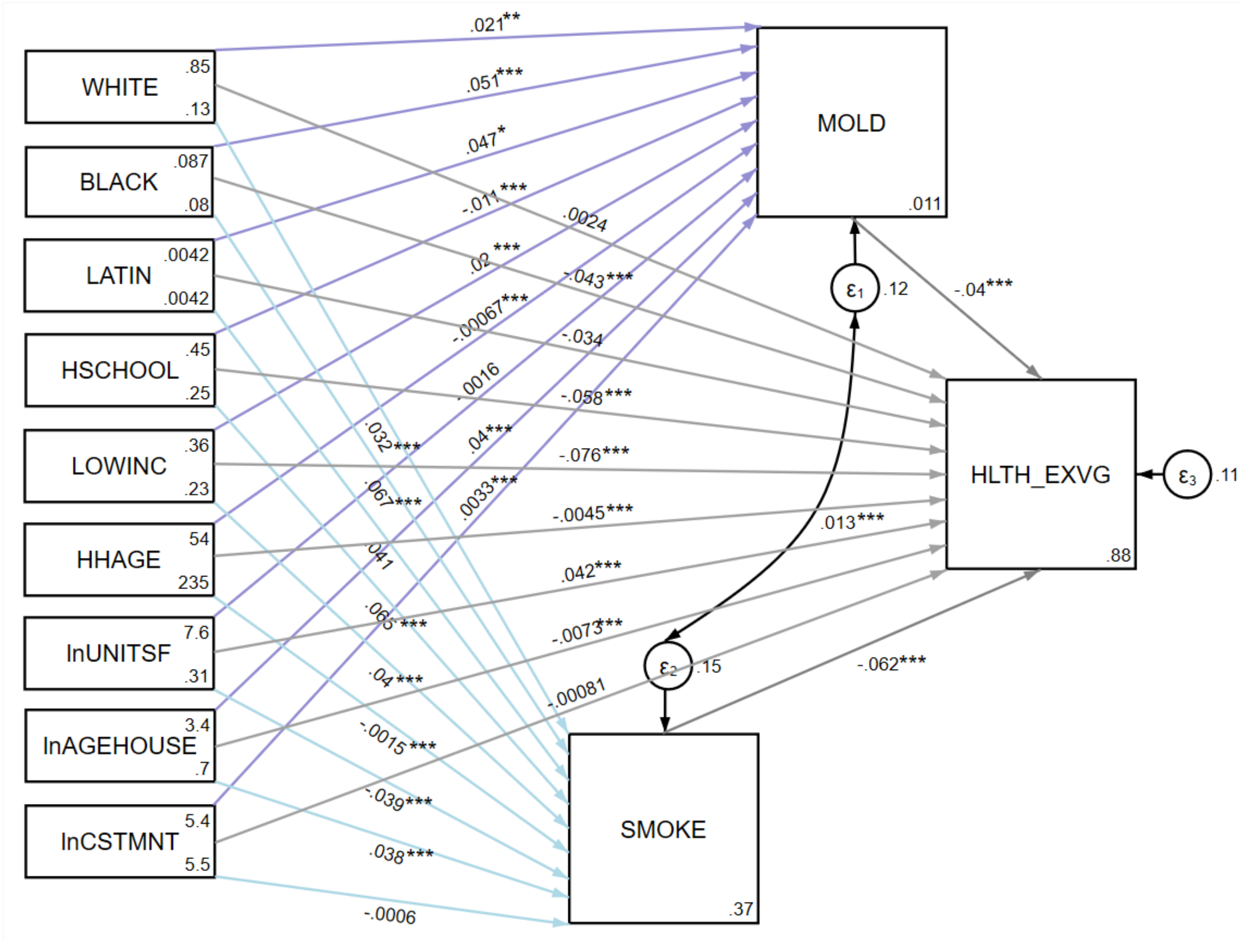

Figure 1. Mediation model of the homeowner.

The mediation model of the homeowner uses the same variables as the renter model except for the lnCSTMNT variable, which is the logged annual cost of maintenance that the homeowner has spent in a year. This mediation model does not contain latent variables, and all the variables were observed variables. Each path (or arrow) is a direct effect from one variable to the other and the coefficients, or in other words, the effect sizes were put right next to each path arrows. Since MOLD and SMOKE conjointly generate poor indoor air quality, MOLD and SMOKE were correlated in the model. This procedure generates a Kronecker product of the error terms in the MOLD (ε_1) and SMOKE (ε_2) estimations. Regarding the numbers listed in the boxes of the exogenous variables, the mean of each exogenous variable is listed in the upper right corner and the variance in the lower right corner. Regarding the endogenous mediators (i.e., MOLD and SMOKE) and outcome (i.e., HLTH_EXVG) variables, the intercept of each path estimation towards these variables is listed in the lower right corner of these boxes. Regarding the three error terms of all the maximum likelihood estimations (i.e., ε_1, ε_2, ε_3), the mean of each error term is listed right next to the circles, whereby the correlation between the error terms of MOLD and SMOKE was 0.013 and significant. The significance of each direct effect was evaluated by the *Z*-statistics.

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

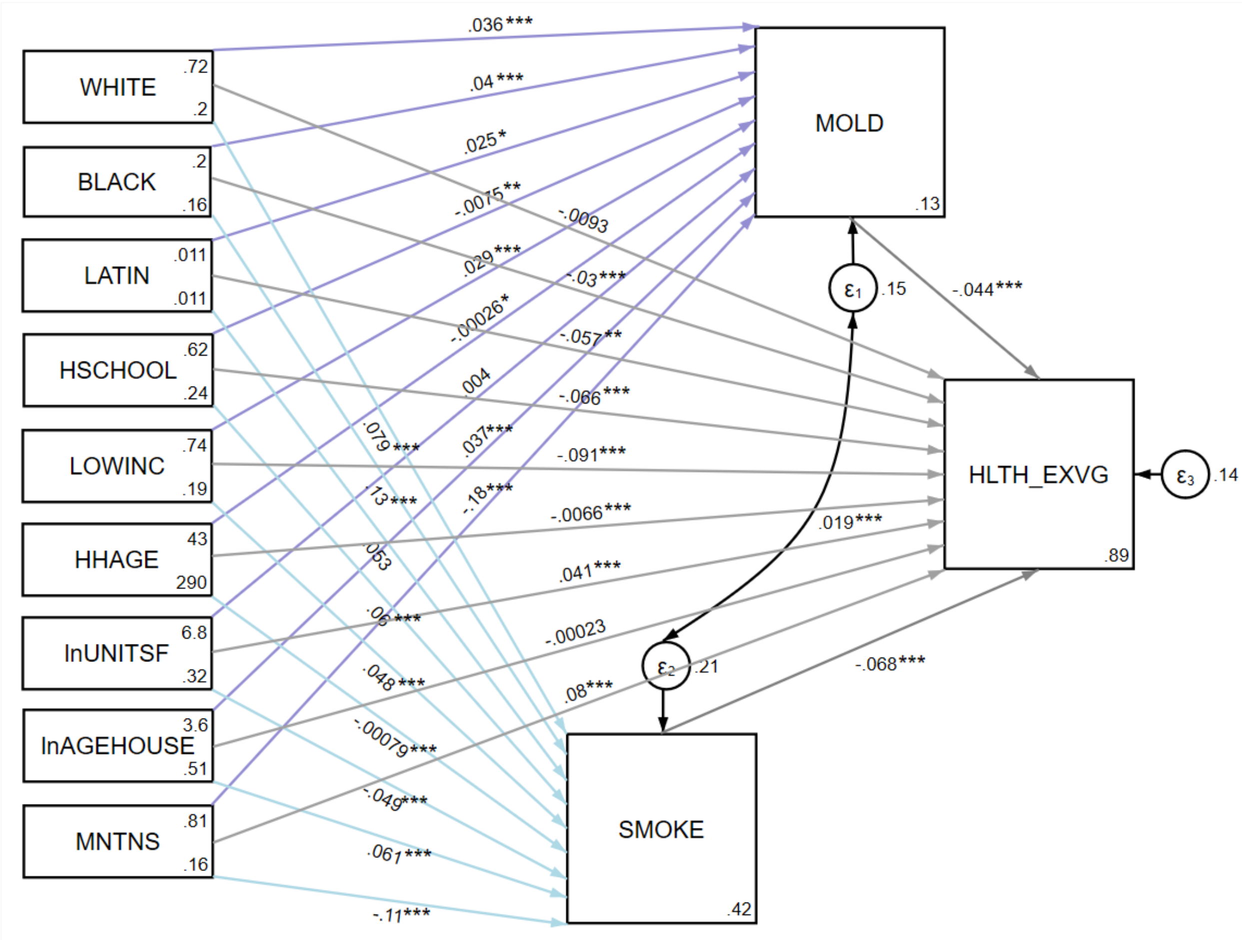

Figure 2. Mediation model of the renter.

The mediation model of the renter uses the same variables as the homeowner model except for the MNTNS variable, which is an indicator variable whether the renter was completely or partially satisfied with the maintenance in the renter's dwelling. This mediation model does not contain latent variables, and all the variables were observed variables. Each path (or arrow) is a direct effect from one variable to the other and the coefficients, or in other words, the effect sizes were put right next to each path arrows. Since MOLD and SMOKE conjointly generate poor indoor air quality, MOLD and SMOKE were correlated in the model. This procedure generates a Kronecker product of the error terms in the MOLD (ε_1) and SMOKE (ε_2) estimations. Regarding the numbers listed in the boxes of the exogenous variables, the mean of each exogenous variable is listed in the upper right corner and the variance in the lower right corner. Regarding the endogenous mediators (i.e., MOLD and SMOKE) and outcome (i.e., HLTH_EXVG) variables, the intercept of each path estimation towards these variables is listed in the lower right corner of these boxes. Regarding the three error terms of all the maximum likelihood estimations (i.e., ε_1, ε_2, ε_3), the mean of each error term is listed right next to the circles, whereby the correlation between the error terms of MOLD and SMOKE was 0.019 and significant. The significance of each direct effect was evaluated by the *Z*-statistics.

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

Direct effects

The direct effects, or in other words, the coefficients for each path are estimated by three estimation models of each sample. Table 2 explicitly shows how the coefficients of each path from one variable to the other are estimated. Noted again is that the estimation method used for these models is not an Ordinary Least Square (OLS), but a maximum likelihood estimation that fits all the exogenous variables into a Binominal distribution. The significance is evaluated by the *Z*-test, like in a Probit regression. My mediation model based on a maximum likelihood estimation and is different from a Probit model in the sense that the Probit model fits the data to a cumulative density function of a Normal distribution that resembles a logistic function in a Logit regression, while my maximum likelihood estimation fits the data to a probability density function of a Binominal distribution.

Table 2 shows how the coefficients in Figures 1 and 2 are generated by using the samples of the homeowner and renter. Each coefficient corresponds to the coefficients attached to each arrow (i.e., direct effects) in Figures 1 and 2. The coefficients of the output are interpreted in terms of how much in *Z*-scores would have to move. However, such an interpretation is not informative in social science research so that this study will rely on the different magnitudes and directions of the coefficients between homeowners and renters. For the same reason, in many studies using structural equation modeling techniques, the coefficient is termed as an ‘effect size’ in the sense that I interpret the magnitudes and signs of the coefficients and put less emphasis on interpreting the coefficients by the change in *Z*-scores.

In Table 2, for each sample type, three models were estimated. The dependent variables were MOLD, SMOKE, and HLTH_EXVG, whereby the independent variables were the exogenous variables. A convenient way to see how each independent variable is chosen into the model can be done by following each path in Figures 1 and 2. For each arrow, the starting point is a variable that is chosen into the estimation model, and the destination is the dependent variable.

$$MOLD_i = \beta_0^M + \beta_1^M \mathbf{RACE}_{i,1} + \beta_2^M \mathbf{SOCIO}_{i,2} + \beta_3^M \mathbf{HOUSE}_{i,3} + \beta_4^M \mathbf{MNTNC}_{i,4} + \varepsilon_1$$

$$SMOKE_i = \beta_0^S + \beta_1^S \mathbf{RACE}_{i,1} + \beta_2^S \mathbf{SOCIO}_{i,2} + \beta_3^S \mathbf{HOUSE}_{i,3} + \beta_4^S \mathbf{MNTNC}_{i,4} + \varepsilon_2$$

$$HLTH_i = \beta_0^H + \beta_1^H \mathbf{RACE}_{i,1} + \beta_2^H \mathbf{SOCIO}_{i,2} + \beta_3^H \mathbf{HOUSE}_{i,3} + \beta_4^H \mathbf{MNTNC}_{i,4} + \beta_5^H \mathbf{IAQ}_{i,5} + \varepsilon_3$$

As for the variables used in Table 2, $MOLD_i$, $SMOKE_i$, and $HLTH_i$ are the dependent variables of MOLD, SMOKE, and HLTH_EXVG, whereby i is the identifier of each observation in the homeowner's or renter's sample – recall, it is a cross-sectional dataset. As for the independent variables, vectors are boldfaced. The vector $\mathbf{RACE}_{i,1}$ consists of the variables WHITE, BLACK, and LATIN. The vector $\mathbf{SOCIO}_{i,2}$ contains variables related to the socioeconomic conditions of the survey respondent and are HSCHOOL, LOWINC, and HHAGE. The vector $\mathbf{HOUSE}_{i,3}$ contains variables related to the dwelling itself and are lnUNITSF and lnAGEHOUSE. The vector $\mathbf{MNTNC}_{i,4}$ contains variables that are related to home maintenance (i.e., intervention) and is lnCSTMNT in the homeowner's sample and MNTNS in the renter's sample. The vector $\mathbf{IAQ}_{i,5}$ contains variables related to poor indoor air quality and are MOLD and SMOKE. The error terms ε_1, ε_2, and ε_3 each corresponds to the error terms in Figures 1 and 2. Except for the intercepts in Table 2, each coefficient and error terms in the three models above correspond to a path in Figures 1 and 2. Last but not least, the superscripts of M, S, and H, indicate that a coefficient is on the path towards MOLD, SMOKE, and HLTH_EXVG.

The standard errors in Models 1, 2, 4, and 5 in Table 2 are the standard errors based on the Seemingly Unrelated correlation between the variance-covariance matrices of MOLD and SMOKE when clustered by 77 counties.

In terms of the different variables used in the homeowner's and renter's samples, lnCSTMNT is the logged annual maintenance cost reported by the homeowner and is only observed in the homeowner's sample. By the same token, MNTNS is a binary indicator variable of whether the renter was completely or partially satisfied with the maintenance service in the rental housing. Both variables proxy the effort of home maintenance and represent the intervention effort discussed in the previous chapter.

Regarding the interpretations of the direct effects, it is noted that each effect size is the association of two variables. This means that there is still the unobserved endogenous effect of mold and smoke present that will later be addressed by the mediation model. For instance, LOWINC in Models 3 and 6 in Table 2 shows how much health would be deteriorated if one is a low-income earner. In other words, it does not contain any information about how mold and smoke as endogenous variables would affect the homeowner or renter. The models that address the endogenous aspect of mold and smoke are the indirect (mediation) and total effect models in Tables 3 and 4.

Table 2. Direct effects of the homeowner and renter

	HOWNER			RENTER		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	MOLD	SMOKE	HLTH_EXVG	MOLD	SMOKE	HLTH_EXVG
WHITE	0.0209**	0.0315***	0.00239	0.0361***	0.0792***	-0.00926
	(0.00891)	(0.00992)	(0.00474)	(0.00753)	(0.0106)	(0.0106)
BLACK	0.0514***	0.0668***	-0.0428***	0.0403***	0.128***	-0.0297***
	(0.0112)	(0.0114)	(0.00682)	(0.00933)	(0.0110)	(0.00897)
LATIN	0.0470*	0.0413	-0.0343	0.0247*	0.0525	-0.0565**
	(0.0268)	(0.0290)	(0.0229)	(0.0144)	(0.0324)	(0.0242)
HSCHOOL	-0.0107***	0.0646***	-0.0581***	-0.00754**	0.0600***	-0.0665***
	(0.00285)	(0.00501)	(0.00337)	(0.00364)	(0.00686)	(0.00498)
LOWINC	0.0199***	0.0403***	-0.0759***	0.0286***	0.0477***	-0.0908***
	(0.00322)	(0.00433)	(0.00327)	(0.00509)	(0.00693)	(0.00452)
HHAGE	-0.000671***	-0.00151***	-0.00445***	-0.000260*	-0.000791***	-0.00655***
	(0.000112)	(0.000138)	(0.000150)	(0.000143)	(0.000248)	(0.000180)
lnUNITSF	-0.00157	-0.0394***	0.0416***	0.00405	-0.0494***	0.0406***
	(0.00272)	(0.00309)	(0.00311)	(0.00452)	(0.00532)	(0.00395)
lnAGEHOUSE	0.0405***	0.0376***	-0.00727***	0.0369***	0.0613***	-0.000228
	(0.00273)	(0.00321)	(0.00165)	(0.00243)	(0.00418)	(0.00283)
lnCSTMNT	0.00330***	-0.000595	-0.000808			
	(0.000543)	(0.000667)	(0.000590)			
MNTNS				-0.178***	-0.107***	0.0799***
				(0.00635)	(0.00541)	(0.00649)
MOLD			-0.0403***			-0.0439***
			(0.00309)			(0.00607)
SMOKE			-0.0624***			-0.0683***
			(0.00363)			(0.00423)
Constant	0.0114	0.369***	0.880***	0.131***	0.420***	0.885***
	(0.0261)	(0.0311)	(0.0273)	(0.0354)	(0.0392)	(0.0310)
Observations	57,919	57,919	57,919	35,730	35,730	35,730
R-Squared	0.012	0.030	0.098	0.042	0.041	0.131

Note. This table shows how the coefficients in Figures 1 and 2 are generated by using the samples of the homeowner and renter. Each coefficient corresponds to the coefficients attached to each arrow (i.e., direct effects) in Figures 1 and 2. The estimation of the direct effects is based on a maximum likelihood estimation, assuming a Binominal distribution. The interpretation of the coefficients is the change in the *Z*-score or simply put the 'effect size.' In Models 1, 2, 4, and 5, the standard errors in the parentheses are the seemingly unrelated errors (i.e., the conjoint product of the errors: Kronecker product) of MOLD and SMOKE. All models are clustered by 77 counties. The overall *R*-Squared was 0.124 in the homeowner's and 0.185 in the renter's sample, whereby all the models converged to the optimum based on the log pseudo-likelihood test. The variable lnCSTMNT is the logged annual cost of maintenance reported by the homeowner. MNTNS is an indicator variable of whether the renter was completely or partially satisfied with the maintenance service in the rental housing.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The interpretation of the direct effects (or coefficients in Figures 1 and 2) shows that there is significant evidence that mold and smoke are present in dwellings of White and Black homeowners and renters when compared to Asian households. The significant and positive output in Models 1, 2, 4, and 5 show that WHITE and BLACK have a positive and significant effect size towards having mold or smoke in their homes. Yet, when looking at the health estimations in Models 3 and 6, White residents enter the data with not a significant health deterioration, while African Americans show a very significant negative health status compared to Asians. As for the Latin population, insignificant or small negligible significant results were observed except for the coefficient in Model 6, the health estimation. Thus, Latin renters showed a significantly negative health aspect like the African American community.

Regarding the outcomes of the race variables, the direct effects only interpret how each race group entered the regression model compared to Asians who have a similar health status as the White population. Later, in the postestimation section, it will be shown that, except for the African American population, the direct effects towards the health of WHITE and LATIN is yet ambiguous in the sense they do not show a consistent result. That is, there are some differences in terms of significance and whether they were affected by mold or smoke. As it will be shown later, a comparison of Models 2 and 6 in Tables 2 and 7 suggests that the most consistent output by race groups can be found by Black homeowners and renters, and White renters, whereby these two racial groups show a large health discrepancy between homeowners and renters.

The direct effects of the HSCHOOL variable consistently show a significant output along with all estimation models. Recall that HSCHOOL is a binary indicator variable whether the survey respondent was having a lower than a high school education and was a proxy for low educated populations. Models 1 and 4 suggest that survey respondents in my sample rather do not live in a moldy environment yet, according to Models 2 and 5, were heavily exposed to cigarette smoke. This confirms Hewett, Sandell, Reece, and Bohac's (2002) finding that second-hand transfer smoke is mostly found in low-income and renter households. The general health effect of high school or lower educated survey respondents in Models 3 and 6 showed that they have a deteriorating health condition, which again requires addressing the endogenous effect of poor indoor air quality. Regarding the negative coefficient of HSCHOOL in the regression of MOLD, later in the analysis of the indirect effect (Table 3) that mediates through both the MOLD and SMOKE variables, it is shown that even though there is less mold than smoke detected in high school or lower-educated populations, conjointly, the indirect effect shows that mold and smoke together deteriorate the health of the dwelling occupant.

The LOWINC variable shows a similar yet different direct effect outcome compared to the HSCHOOL variable. As for low-income residents, both the homeowner and renter suffered under mold and smoke, as shown in Models 1, 2, 4, and 5. This is a different outcome from the HSCHOOL variable, where only mold was significantly present at their homes. In fact, LOWINC more accurately captures the dwelling environment of the underprivileged population than HSCHOOL in the sense that it directly captures the amount of wealth of the resident. Regarding the health outcome, LOWINC showed a negative direct effect towards health, whereby the renter's coefficient magnitude was larger. This indicates that low-income renters suffered more than the homeowners. Again here, I would suspect that there should be a mediating factor that would have caused this result.

Another demographic variable that was included as an exogenous variable in my model was the household head's age: HHAGE. It is noted again that the American Housing Survey (AHS) recognizes the first respondent to the survey as the household head, and it does not depend on gender or the financial power of that person in the household. The coefficients throughout all the models in Table 2 are very small. All of them are less than 0.01 and indicate that the effect of the age pertinent to the presence of mold or smoke is very small. This means that there is not much inference that age is related to living in an environment of mold or smoke. Regarding the health outcome estimations in Models 3 and 6, older people did not report a good health condition whereby the renter's health was deteriorating more than the homeowner's by age. Yet, again, the effect sizes were very minimal. However, even though it is small, the negative effect sizes of the health models in Models 3 and 6 indicate that older people do not live in good health.

The variables that proxied the condition of the home were lnUNITSF and lnAGEHOUSE. While the increase in the dwelling size would also entail information about more income and a better living arrangement, a greater value of lnAGEHOUSE proxied a more dilapidated home and worse living condition. As for the significant coefficients of these two variables in Models 1, 2, 4, and 5, a bigger unit was associated with less mold and smoke for both the homeowner and renter. By the same analogy, older homes were positively and significantly related to having mold or smoke. Regarding the health effect from the dwelling condition, a bigger unit significantly enhanced the health of the homeowner and renter. The deteriorating health effect of somebody living in an older home was only observed in the homeowner's sample, while the mediation effect in Table 3 will show that mediators of mold and smoke generate a similar effect for both the homeowner and renter. This again shows the superiority of an indirect mediation model that incorporates the endogenous effects that harm one's health.

In this study, I was also examining how an intervention effort would affect one's health. I was assuming that home maintenances would decrease the hazards of health, as stated by Saegert, Klitzman, Freudenberg, Cooperman-Mroczek, and Nassar (2003), who found that home maintenance has a positive effect on the health of the resident. While in Table 2, lnCSTMNT showed an insignificant effect on the homeowner's health, MNTNS showed a positive and significant maintenance effect on the renter's health. However, contrary to the renter, the effect of the intervention was small in the homeowner's model (see Model 1). Thus, an investment in home maintenance benefited the renter more than the homeowner. The underlying reason for this result can be found in the initially given health status of the homeowner and renter. Given that the renter's health was worse off than the homeowner, the increment of health (i.e., effect size) of the renter is expected to be greater.

Regarding the relationship between mold, smoke, and health, Models 3 and 6 obviously show a negative relation of the generators of poor indoor air quality with health. Noteworthy is that the effect sizes of the renter's sample are larger than those of the homeowner. This indicates that more mold and smoke was found in a renter's dwelling. Comparing the coefficient magnitudes of mold and smoke, the coefficients of SMOKE were larger than MOLD in both samples. That is, the effect of health deterioration through SMOKE was greater than MOLD.

Indirect effects

The hallmark and the main finding of this study come from the analysis of the mediation or, in other words, the indirect effects via MOLD and SMOKE. The strength of the indirect effect model lies in incorporating the endogenous variables as mediators. In other words, it shows how the information of the exogenously given variables embedded in MOLD and SMOKE would ultimately affect the health status of the resident. For this reason, sometimes, the mediators are also called 'instrumental variables,' in a sense that they predict the outcome of health on behalf of the exogenous variables. However, a caveat here is that they are not the same instrumental variables that we usually acknowledge in Econometrics literature. That is, the endogeneity in the structural equation model is about a structural endogeneity based on the relationships among variables and does not pertain to omitted variable bias, selection bias, measurement error, or simultaneity. The reason why the concept of instrumental variables fits into the mediation framework is because the concept of mediation (or indirect effect) relates to estimating the outcome variable (i.e., the health status of the resident) by the mediators (i.e., mold and smoke) that embed the information of the exogenous variables. Thus, in a mediation framework, mold and smoke are not simply mold and smoke as a standalone variable but are substitutions of the exogenous variables of the residents (e.g., race, income, education, age, housing condition, intervention effort).

As mentioned before, I correlated the error terms in the estimations of MOLD (ε_1) and SMOKE (ε_2). In the direct effect model, these errors are from Models 1 and 2 in the homeowner's and Models 4 and 5 in the renter's sample. These errors were then multiplied for each combination of observations (i.e., Kronecker product) and weighted in the estimations of Models 1 and 2 in the homeowner's sample and Models 4 and 5 in the renter's sample. The conceptual argument behind this procedure is that mold and smoke are conjointly generating poor indoor air quality. As shown in Figures 1 and 2, the correlations of the error terms of MOLD and SMOKE are statistically significant at one percent level based on a *Z*-test whereby the correlation between MOLD and SMOKE was larger in the renter's sample.

Obtaining the indirect effect would involve multiplying the effect sizes in the MOLD and SMOKE estimations. Since mold and smoke are conjointly related to generating poor indoor air quality, I strongly felt that the aggregate indirect effect should be reported in this study. Individual indirect effects through MOLD or SMOKE would not make sense because mold and smoke were estimated by the same error term in Models 1, 2, 4, and 5 of Table 2. Thus, the indirect effect results in Table 3 are the aggregated indirect effects that go through both MOLD and SMOKE.

Regarding the effect sizes reported in Table 3, it is noted that this table is not a table that reports regression outputs. It lists the computed aggregate indirect effects that lead towards HLTH_EXVG. Evaluated by the *Z*-test, the Z-test is conducted by the multiplications of the coefficients, normalized by the standard errors reported in the direct effect models, and the computed standard errors are reported in the parentheses of Table 3. The most prominent result in Table 3 is that all aggregate indirect effect sizes of the renter are larger than that of the homeowner. In other words, the hazardous effect of poor indoor air quality (or environmental injustice) affects the renter more than the homeowner, and the intervention would benefit the renter more than the homeowner.

Table 3. Indirect effects of the homeowner and renter

HLTH_EXVG	(1) HOWNER	(2) RENTER
WHITE	-0.0028***	-0.0070***
	(0.00005)	(0.00081)
BLACK	-0.0062***	-0.0105***
	(0.00065)	(0.00089)
LATIN	-0.0045**	-0.0047**
	(0.00210)	(0.00225)
HSCHOOL	-0.0036***	-0.0038***
	(0.00044)	(0.00055)
LOWINC	-0.0033***	-0.0045***
	(0.00037)	(0.00074)
HHAGE	0.0001***	0.0001***
	(0.00001)	(0.00002)
lnUNITSF	0.0025***	0.0032***
	(0.00029)	(0.00047)
lnAGEHOUSE	-0.0040***	-0.0058***
	(0.00031)	(0.00051)
lnCSTMNT	-0.0001*	
	(0.00005)	
MNTNS		0.0151***
		(0.00142)

Note. The evaluation of the indirect effects is done by the *Z*-statistics. This table shows the aggregate indirect effects of the paths that go through both MOLD and SMOKE, and towards the health outcome HLTH_EXVG. That is, it is the sum of the multiplication of the indirect paths through MOLD and SMOKE:$\left(\beta_{(\text{Exogenous Variable}\rightarrow\text{MOLD})} * \beta_{(\text{MOLD}\rightarrow\text{HLTH})}\right) + \left(\beta_{(\text{Exogenous Variable}\rightarrow\text{SMOKE})} * \beta_{(\text{SMOKE}\rightarrow\text{HLTH})}\right)$, and they were evaluated by the *Z*-statistics. Like the previous analyses of homeowners and renters, also in this table, the homeowner and renter models differ in using the lnCSTMNT variable in the homeowner's, and MNTNS variable in the renter's sample. The reason for computing the aggregate indirect effect comes from the fact that MOLD and SMOKE conjointly generate poor indoor air quality. The robust standard errors in the parentheses were clustered by 77 counties and used in the evaluation by the *Z*-statistics.

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

As for the race groups, we previously have seen in Table 2 that WHITE and LATIN were showing insignificant results in Models 3 and 6. The indirect effects of WHITE and LATIN now show that the mediation through poor indoor air quality would generate a negative health impact, and the effect on the renter is greater than the homeowner. Likewise, for the African American population, both the homeowner and renter suffered from poor indoor air quality. Regarding the differences between homeowners and renters by race groups, the Latin population showed a very small difference of being close to zero. However, WHITE and BLACK showed a larger discrepancy between the effect sizes of homeowners and renters – the largest among all the exogenous variables. This result also can be interpreted in a way that, if compared to Asian renters, the difference of Black and White renters' health is larger than the discrepancy between Black and White homeowners if compared to Asian homeowners. Recall that the Asian group is the healthiest racial/ethnic group in the sample. Thus, if one sets Asians as a desirable comparable group, the health condition is less distinguishable when it comes to homeowners, while this difference gets relatively larger in the renter's sample. Considering that better health is also acquainted with higher income and that the Asian group in my sample presented the highest income group, a smaller difference in income among homeowners (comparatively to renters), shows that one's income is the reason for the large gap in the health outcomes of WHITE and BLACK. Notable is that the Latin group showed a small difference compared to Asians. This result can be routed back to the earlier argument made by Grineski and Hernandez (2010) that the health outcome of the Latin population is partially disrupted so that they show an extremely healthy condition. Another notable result is that among the negative effect sizes across all results in Table 3, the coefficient of Black renters was the largest, as well as the difference between homeowners and renters. This strongly suggests that the African American renter population suffered most from environmental injustice.

Among the largest discrepancies between the effect sizes of homeowners and renters, LOWINC reported the fourth-largest gap between the two sample groups – after BLACK, WHITE, and lnAGEHOUSE. This shows the importance of a mediation model that explicitly shows that lower-income populations suffer more under environmental injustice.

Regarding the results that showed similar magnitudes in the two samples in terms of the mediation effect of poor indoor air quality, HSCHOOL and HHAGE showed similar effect sizes in the homeowner's and renter's models. Yet, one difference that distinguishes these two variables is that HSCHOOL had a significant negative effect, while HHAGE showed a positive and significant effect on health. However, given the extremely small coefficients, the correct interpretation of the effect of HHAGE is that it has a significant zero effect size on health. In other words, the age of the household head would not be relevant when it comes to the mediation effect of poor indoor air quality. The reason for this result can be found in Table 1, where around 80 to 85 percent of the homeowners and renters reported excellent or very good health status. Thus, since the survey respondents in the sample were already in good health, this would have made the age of the respondent almost irrelevant. Meanwhile, low education proxied by the HSCHOOL variable had a negative effect on the occupant's health when mediated through poor indoor air quality, whereby the renter suffered more under environmental injustice than the homeowner.

Regarding the living arrangements of the residents, lnAGEHOUSE showed the third-largest difference in terms of the effect sizes of homeowners and renters. Thus, not only does the age of the house affect the occupant's health, but it was also severely different by homeowner and renter. As it was shown in the summary statistics in Table 1, the age of the house itself was not much different between homeowners and renters. Yet, the severely different outcome when mediated through mold and smoke evidently shows that renters are worse off when they live in older dwellings with poor indoor air quality.

Contrary to lnAGEHOUSE, lnUNITSF measures the positive effect of a larger dwelling. Even though the difference of the negative mediation effect of poor indoor air quality between homeowners and renters is small like LATIN, it still signals that a larger dwelling offsets the negative externality of poor indoor air quality. Caution is required when interpreting the effect sizes of lnUNITSF or lnAGEHOUSE because they do not represent a large dwelling or old house in absolute terms. These variables measure the increment of a one-unit increase of lnUNITSF (i.e., ten square footage) or lnAGEHOUSE (i.e., ten years) and thereby affected the health of the homeowner or renter.

The variables that proxied intervention through home maintenance were lnCSTMNT (homeowner's sample) and MNTNS (renter's sample). The former was the logged annual maintenance cost reported of the homeowner, and, the latter, whether the renter was satisfied with the maintenance service by the landlord. Like the output of the direct effect models in Table 2, also in Table 3's mediation effect, lnCSTMNT had a very small coefficient – close to zero, while the coefficient was significant at a ten percent level. Comparing the outputs of lnCSTMNT in Tables 2 and 3, it is obvious that the identification of the coefficient peddles around zero. This is a strong indicator that the intervention effort of the homeowner has very little influence on the homeowner's health. Contrary to lnCSTMNT, the MNTNS variable delivered a strong message that, indeed, an intervention improves the renter's health, and this was consistent throughout the results reported in Tables 2 and 3.

Regarding the relationship between home maintenance and resident's health, Patino and Siegel (2018) document that factors such as building age or poor maintenance would severely affect the health of its residents. For example, based on archival research on previous studies, Thomson, Petticrew, and Morrison (2001) found that most of the interventions through rehousing, refurbishment and relocation, community regeneration, or the use of energy-efficient measures improved the health condition of its residents. Likewise, a similar archival study by Saegart, Klitzman, Freudenberg, Cooperman-Mroczek, and Nassar (2003) found that a resident's housing education based on the participants' knowledge, attitudes, and behavior significantly advanced the health status of its residents.

Summing up the main findings pertinent to the indirect effect of poor indoor air quality, I found that the indirect effect size of poor indoor air quality on the renter was larger than that of the homeowner. This indicates that poor indoor air quality negatively affects the renter more than the homeowner. Also, the indirect effect sizes of the intervention variables were larger in the renter's sample, which indicates that the renter benefits more from home maintenance than the homeowner.

Regarding the interpretation of the variables, among the three race groups, only WHITE and BLACK showed a meaningful indirect effect based on the difference between homeowners and renters, while the African American population showed the largest negative indirect effect of poor indoor air quality among all variables. Regarding variables that showed a similar effect size in both the homeowner's and renter's sample, LATIN and HSCHOOL showed a significant negative indirect effect. The effect size of HHAGE was very close to zero, which corresponds to the already healthy status of the survey respondent. LOWINC had the fourth-largest gap between homeowners and renters – after BLACK, WHITE, and lnAGEHOUSE, whereby the negative indirect effect of poor indoor air quality was observed greatest by the sequence of BLACK, WHITE, lnAGEHOUSE, LATIN, and LOWINC. The lnAGEHOUSE variable showed the third-largest difference in the effect sizes between homeowners and renters. Despite the fact that the age of the house variable was similarly distributed among homeowners and renters, the mediated indirect effect of poor indoor quality seems to deteriorate the renter's health more than the homeowner's when a renter was living in an older dwelling. Contrary to lnAGEHOUSE, lnUNITSF measured the positive effect of a larger dwelling. The finding of this variable showed that a larger dwelling offsets the negative externality of poor indoor air quality. The home maintenance variables proxied by the annual maintenance cost reported by the homeowner and the maintenance satisfaction of the renter showed that home maintenance has little correlation with the homeowner's health. Therefore, like HHAGE, home maintenance adds little to nothing to the homeowner's health. However, MNTNS showed the opposite result. A greater maintenance satisfaction of the renter significantly increased the health condition of the renter when mediated through poor indoor air quality.

Total effects

The total effect is the sum of the direct effect and indirect effects. As noted before, while all single paths from one variable to the other is called a direct effect, the direct effect in the total effect pertains to the path from the exogenous variable directly to the outcome variable, whereby the indirect effect is specified by the path through the mediators. Again, the indirect effect in the total effect was computed as an aggregate indirect effect of both MOLD and SMOKE.

The interpretation of the total effect sizes in Table 4 is similar, as I have done in the previous table on the indirect effects. The difference between the outputs in Tables 3 and 4 is that Table 4 adds the direct effect from the exogenous variable towards the health variable (i.e., the results of Models 3 and 6 in Table 2), on top of the mediated aggregate indirect effects reported in Table 3. Due to this addition, in general, the total effect reports a larger effect size than the indirect effect output.

Table 4. Total effects of the homeowner and renter

HLTH_EXVG	(1) HOWNER	(2) RENTER
WHITE	-0.0004***	-0.0162
	(0.00483)	(0.01058)
BLACK	-0.0490***	-0.0402***
	(0.00692)	(0.00888)
LATIN	-0.0387*	-0.0612**
	(0.02313)	(0.02452)
HSCHOOL	-0.0617***	-0.0702***
	(0.00333)	(0.00493)
LOWINC	-0.0792***	-0.0953***
	(0.00325)	(0.00472)
HHAGE	-0.0043***	-0.0065***
	(0.00015)	(0.00017)
lnUNITSF	0.0441***	0.0438***
	(0.00312)	(0.00379)
lnAGEHOUSE	-0.0112***	-0.0060**
	(0.00168)	(0.00306)
lnCSTMNT	-0.0009	
	(0.00061)	
MNTNS		0.0950***
		(0.00674)

Note. The evaluation of the total effects is done by the *Z*-statistics. This table shows the aggregate total effects of the paths that go through both MOLD and SMOKE, and towards the health outcome HLTH_EXVG. The total effect was computed by the summation of the direct and the aggregate indirect effects of MOLD and SMOKE together: $\beta_{(\text{Exogenous Variable}\rightarrow\text{HLTH})} + (\beta_{(\text{Exogenous Variable}\rightarrow\text{MOLD})} * \beta_{(\text{MOLD}\rightarrow\text{HLTH})}) + (\beta_{(\text{Exogenous Variable}\rightarrow\text{SMOKE})} * \beta_{(\text{SMOKE}\rightarrow\text{HLTH})})$, and they were evaluated by the *Z*-statistics. Like the previous analyses of homeowners and renters, also in this table, the homeowner and renter models differ by using the lnCSTMNT variable in the homeowner's sample and MNTNS variable in the renter's sample. The robust standard errors in the parentheses are clustered by 77 counties and used in the evaluation by the *Z*-statistics.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Regarding the race variables, the total effect on the health of the White renter shows no significance at all. Considering that this variable in the renter's sample showed a significant result in the mediation model (Table 3), the reason why this variable shows an insignificant result comes from the insignificant direct effect that has a stronger influence than the indirect effect when computing the total effect. Thus, this result concludes that the mediation effect of poor indoor air quality is not sufficiently large to change the result of the insignificant direct effect.

Another insignificant result was observed by the variable lnCSTMNT, which was the proxy for the homeowner's intervention effort. Regarding this variable, in the previous analyses (i.e., Tables 2 and 3), lnCSTMNT showed an output of a small coefficient magnitude at a very low or no significance level. This pattern remains in the total effect model in Table 4. Thus, the improvements made through maintenance remains almost irrelevant for the homeowner.

Other than these two insignificant results, all other exogenous variables showed a significant result with the expected signs. However, unlike the indirect effects in Table 3, the total effects did not consistently show a larger effect size magnitude of the renter over the homeowner. Those results signal that, in such cases, the direct effect had a stronger influence than the indirect effect. Such a result could be found by BLACK, lnUNITSF, and lnAGEHOUSE, whereby lnUNITSF showed a very similar magnitude in both the homeowner's and renter's sample.

One interesting finding was observed in the LATIN variable. While this variable showed only significance in the renter's direct effect model, in the indirect and total effect models (i.e., Tables 3 and 4), it showed a significant result. This indicates that mediation through poor indoor air quality enforced the total effect to be significantly negative. Thus, while the direct effect of LATIN does not deliver a significant health outcome, the indirect effect evidently shows that poor indoor air quality damaged the health of Latin Americans.

As for the discrepancy between homeowners and renters in terms of effect sizes, LOWINC showed the largest gap between homeowners and renters, followed by HSCHOOL and BLACK. This shows that most of the time, poor indoor air quality makes a severe difference in terms of environmental injustice when the resident was coming from a low income and low educational background. A finding that bolsters this argument is found in the following Table 5 that compares the direct, indirect, and total effects of the homeowners and renters, where LOWINC and HSCHOOL consistently show a greater effect size in the renter's sample, while the variable BLACK followed the pattern in the direct effect model.

The smallest gap between the homeowner and renter was observed in the lnUNITSF variable. This result indicates that for both the homeowner and renter, the increase in the unit size offsets the negative effect of poor indoor air quality and does not discriminate by the homeowner or renter. Noted is here again that the relationship between this variable and the health variable is not about the absolute size of the dwelling. It is about whether an increment of the size of the dwelling affects the homeowner or renter's health by how much.

As for the HHAGE variable, the same pattern was observed in terms of the effect size magnitude between the homeowner and renter. Again, in the total effect model, HHAGE showed a minimal difference between the homeowner and renter, while the effect sizes of both samples remained close to zero. It is emphasized again that the small effect size of the HHAGE variable comes from the healthy majority of survey respondents.

In sum, the results in the total effect section showed a little different result compared to the very consistent and significant results of the mediation effects in Table 3. As aforementioned, the total effect is the sum of the direct and indirect effects. Except for WHITE and lnCSTMNT, all other exogenous variables showed a significant result, with the expected signs attached to them.

Among the significant results, BLACK, lnUNITSF, and lnAGEHOUSE showed a larger effect on the homeowner's side, while LATIN, HSCHOOL, LOWINC, HHAGE, and MNTNS (compared to lnCSTMNT) had a larger effect size in the renter's sample.

As for the discrepancies between homeowners and renters in terms of effect sizes, LOWINC showed the largest gap between homeowners and renters, followed by HSCHOOL and BLACK. This shows that most of the time, poor indoor air quality makes a severe difference in terms of environmental injustice when the resident was coming from a low income and low educational background. As for the variable BLACK, even though the gap in effect sizes between the homeowner and renter was large, it showed a greater magnitude in the homeowner's sample. This means that the direct effect has a larger influence on the total effect, whereby the renter has a larger effect size only when it is mediated through poor indoor air quality.

Effect size comparisons

In this section, I compare the effect sizes of the direct, indirect, and total effects of the homeowner and renter. An important note when interpreting the results is that I determined insignificant effect sizes (i.e., coefficients) or computations that included an insignificant coefficient. In Tables 5 and 6, I marked them as "N.S.," which stands for "not significant."

Table 5 exhibits the results that conclude the entire empirical analysis of this chapter. Columns 1, 2, and 3 in Table 5 reflect the results in the previous tables where I compared the effect sizes of the homeowner and renter. The evaluation of the effect sizes between homeowners and renters was based on whether the total effect is following the pattern of the result in the direct or indirect effect or whether it showed a consistent pattern throughout all types of effects. The purpose of this analysis was to find a consistent pattern throughout all types of effects. A consistent pattern pertinent to the health discrepancy of the homeowner and renter was only observed in HSCHOOL and LOWINC.

Regarding the interpretation of the results in Table 5, HSCHOOL and LOWINC consistently showed that there is a health discrepancy between homeowners and renters, whereby a larger health deterioration was observed in the renter's sample. Based on the sequence of all the analyses on the exogenous variables, this is the ultimate finding in this study that the renter's underprivileged socioeconomic status of low education and income is exacerbated by the environmental injustice of the renter when compared to the homeowner, and that the health deterioration through poor indoor air quality has a stronger tie to one's socioeconomic status than the biological demographic condition.

Regarding the HHAGE variable, as elaborated before, HHAGE always showed similar effect sizes in the homeowner and renter's samples and was close to zero. Thus, the relationship between the household head's age and the direct and mediated health condition by homeowner and renter is difficult to determine. It would be better to say that age is almost irrelevant when it comes to the effect of poor indoor air quality. As elaborated before, the primary reason for this result comes from the fact that around 80 to 85 percent of the survey respondents in the data was already healthy and reported an excellent or very healthy status.

As for the evaluation where the total effect followed the pattern of the direct effect, BLACK showed that the homeowner was affected more than the renter. This result might confuse the reader as to why someone with more wealth would suffer more. However, when comparing the effect sizes of BLACK in the indirect effect (Table 3) and direct effect (Table 2) tables, the indirect effect through poor indoor air quality shows that the renter was still worse off, whereby the effect size in the total effect was dominated by the direct effect. This indicates that the given health condition of African Americans had a stronger health outcome than the mediated effect through mold and smoke. In other words, comparatively, African Americans had a worse health condition compared to the Asian population, yet, the indirect effect of poor indoor air quality was not sufficiently large to change the result in the total effect outcome.

As for lnUNITSF, where the direct effect was showing a stronger effect than the mediated indirect effect, as mentioned several times before, the effect sizes in the direct, indirect, and total effect of the homeowner and renters were very similar. Noted again is that the effect size of lnUNITSF is not about the absolute dwelling size, but how much one will improve one's health if the unit goes larger by one unit (i.e., ten squared footage). Taken together, the result of lnUNITSF should be interpreted as an increase in the dwelling size would equally benefit the homeowner and renter.

Table 5. Effect size comparisons of the homeowner and renter

HLTH_EXVG	(1) Direct Effect	(2) Indirect Effect	(3) Total Effect	(4) Evaluation
WHITE	N.S.	H < R	N.S.	Inconclusive
BLACK	H > R	H < R	H > R	H > R
LATIN	N.S.	H < R	H < R	Inconclusive
HSCHOOL	H < R	H < R	H < R	H < R
LOWINC	H < R	H < R	H < R	H < R
HHAGE	H ≈ R ≈ 0	H ≈ R ≈ 0	H ≈ R ≈ 0	H ≈ R ≈ 0
lnUNITSF	H ≈ R	H ≈ R	H ≈ R	H ≈ R
lnAGEHOUSE	N.S.	H < R	H > R	Inconclusive
lnCSTMNT & MNTNS	N.S.	H < R	N.S.	Inconclusive

Note. Compared are the effect sizes (i.e., coefficients) of homeowners and renters in the direct, indirect, and total effect models. If any of the coefficients of the homeowner or renter was insignificant, it was concluded as inconclusive. The evaluation of the effect sizes between homeowners and renters was based on whether the total effect is following the pattern of the result in the direct or indirect effect or whether it showed a consistent pattern throughout all types of effects. The purpose of this analysis was to find a consistent pattern throughout all types of effects. A consistent pattern pertinent to the health discrepancy of the homeowner and renter was only observed in HSCHOOL and LOWINC.
H: Homeowner
R: Renter
N.S.: Not significant.

In order to make sure that this study has a numerical comparison of the three effect types, I also analyzed the ratios of each effect size. There are two practical reasons for this analysis. First, this analysis provides a numerical output that shows the proportion of the indirect effect in the total effect, by how much the direct effect is larger than the indirect effect, and whether the direct effect is as large as the total effect. The second practical reason for this analysis is to compare whether these ratios differ by homeowner and renter, whereby the goal was to find a greater indirect to total effect in the renter's sample.

Again here, if a ratio included a coefficient (i.e., effect size) that was insignificant, I assessed them as an invalid outcome and marked them with "N.S." This would include the ratio of indirect-to-total effect when the direct effect is insignificant because the total effect would carry the insignificant result of the direct effect.

Pertinent to the interpretation of each ratio, the ratio of "Indirect Effect/Total Effect" measures the proportion of the mediated effect in the total effect. This would give us the percentage of how much the mediated effect through poor indoor air quality occupies the total effect. The "Indirect Effect/Direct Effect" ratio measures the ratio between the indirect and direct effect. If the ratio is greater than one, the indirect effect dominates, and if less than one, the direct effect dominates in the total effect. The third ratio that I examined was the ratio of "Total Effect/Direct Effect." If this ratio is close to one, it means that it is sufficient to say that the direct effect is almost equivalent to the total effect. Thus, in such a case, we can say that the direct effect model would sufficiently substitute the total effect model.

The results in Table 6 lists all the ratios discussed in the previous paragraph. Regarding the indirect-to-total effect ratio, most of them showed very similar results as in the indirect-to-direct effect ratio. This means that the total effect was mostly dominated by the direct effect. This can be confirmed by the total-to-direct effect ratio, where most of the ratios were revolving around the value one. One exception was found in the indirect-to-total effect ratio of the renter's lnAGEHOUSE outcome. The ratio of 0.96 indicates that the indirect effect through poor indoor air quality explains most of the renter's health when it comes to the mediation effect of older homes. As for the ratio in the homeowner's sample, the indirect and direct effects were almost similar, which can be found by the ratio of 0.55 of the indirect-to-direct effect ratio in the homeowner's sample.

As for the ratios where the renter's indirect effect is larger than that of the homeowner, LOWINC and BLACK showed larger indirect-to-total and indirect-to-direct effect ratios. This result shows that low-income and Black renters were suffering more than other socioeconomic groups through poor indoor air quality.

Among the ratios, there were also atypical ratios. One is found in the indirect-to-total and indirect-to-direct effect ratio of the HHAGE variable. The negative sign of these ratios comes from the positive coefficient of the indirect effect and negative coefficients of the total and direct effects. However, as emphasized before, all the coefficients of the HHAGE variable are close to zero so that obtaining the ratios of these effect sizes would not deliver any meaningful interpretation.

Table 6. Ratios of the homeowner and renter

HLTH_EXVG	RATIO	(1) HOWNER	(2) RENTER
WHITE	Indirect Effect / Total Effect	N.S.	N.S.
	Indirect Effect / Direct Effect	N.S.	N.S.
	Total Effect / Direct Effect	N.S.	N.S.
BLACK	Indirect Effect / Total Effect	0.13	0.26
	Indirect Effect / Direct Effect	0.15	0.35
	Total Effect / Direct Effect	1.15	1.35
LATIN	Indirect Effect / Total Effect	N.S.	0.08
	Indirect Effect / Direct Effect	N.S.	0.08
	Total Effect / Direct Effect	N.S.	1.08
HSCHOOL	Indirect Effect / Total Effect	0.06	0.05
	Indirect Effect / Direct Effect	0.06	0.06
	Total Effect / Direct Effect	1.06	1.06
LOWINC	Indirect Effect / Total Effect	0.04	0.05
	Indirect Effect / Direct Effect	0.04	0.05
	Total Effect / Direct Effect	1.04	1.05
HHAGE	Indirect Effect / Total Effect	-0.03	-0.01
	Indirect Effect / Direct Effect	-0.03	-0.01
	Total Effect / Direct Effect	0.97	0.99
lnUNITSF	Indirect Effect / Total Effect	0.06	0.07
	Indirect Effect / Direct Effect	0.06	0.08
	Total Effect / Direct Effect	1.06	1.08
lnAGEHOUSE	Indirect Effect / Total Effect	0.35	0.96
	Indirect Effect / Direct Effect	0.55	N.S.
	Total Effect / Direct Effect	1.55	N.S.
lnCSTMNT	Indirect Effect / Total Effect	N.S.	
	Indirect Effect / Direct Effect	N.S.	
	Total Effect / Direct Effect	N.S.	
MNTNS	Indirect Effect / Total Effect		0.16
	Indirect Effect / Direct Effect		0.19
	Total Effect / Direct Effect		1.19

Note. The ratios were computed by the direct, indirect, and total effect outputs in the previous analyses. A ratio was disqualified if even one of these effects was statistically insignificant.
N.S.: Not significant.

3.3. Postestimation

As a robustness test, I conducted an analysis using a Linear Probability Model (LPM). A Linear Probability Model is an Ordinary Least Square (OLS) regression with a binary dependent variable. It is noted that in such cases, a negative intercept of the predicted model would not grant the viability of the model in the sense that the dependent variable does not contain any negative values – only one or zero. In this sense, it is crucial to have a significantly positive or non-negative intercept. Again, all my models were regressed on two subsamples (i.e., the homeowner and renter), and in both samples, all the constant terms reported a significant positive result.

A refined mediation model by Hayes (2013) uses the same type of regression as in my postestimation section, where the dependent variables are estimated by all the exogenous variables in one model. However, the problem that Hayes' (2013) model faces is the same as with the Sobel method (1982, 1986) – it relies on an Ordinary Least Square (OLS) regression. That is, if the dependent variable is binary, the predicted line should not cross any negative quadrants in the space, and if it does, this would be a wrong prediction of the dependent variable. Luckily, as noted in the previous paragraph, my postestimation model does not contain any negative intercepts. However, despite this risk of a misidentified regression model, it is also noteworthy to explore the linear relationship of the variables to test the robustness of my structural equation model.

One of the refinements that Hayes (2013) has done to overcome the issue of the formation of distributions that are not normally distributed was to bootstrap the error terms of the regressions in the direct effect estimation. Recall that I previously argued that if the estimated direct effect models are not normally distributed, it is difficult to obtain a Normal distribution when the results are combined. For this reason, bootstrapping on a Normal distribution would artificially generate a normally distributed model. In my postestimation model, I bootstrapped the errors of each estimation by 1,000 iterations.

Regarding the conjoint effect of mold and smoke as poor indoor air quality, in my postestimation model, I applied a Seemingly Unrelated Regression (SURE) for Models 1, 2, 4, and 5. I multiplied the errors (i.e., obtained the Kronecker product) of the regressions of MOLD and SMOKE by each sample type and weighted the coefficients with this combined error term. As a side note, the Seemingly Unrelated Regressions (SURE) in Models 1, 2, 4, and 5 are nested models. The notion of being nested only applies when the independent variables in both the MOLD and SMOKE models are identical. Models 1 and 2, and, Models 4 and5 are nested in each other because I applied the same variables in the MOLD and SMOKE models by homeowner and renter.

Other than the procedure for a conjoint error term in the Seemingly Unrelated Regressions (SURE), I also added 77 state-county dummies to every model in Table 7 to control for county-specific location-based attributes such as the different climates across the United States. The primary reason for including these controls comes from the fact that more mold is generated under humid climates. Such naturally produced differences would deter my crude comparison between a homeowner and renter based on their socioeconomic attributes so that there was the necessity to control them in the model. Additionally, considering that the LOWINC variable was generated at the county level, it was also important to control for county-specific attributes in terms of the living condition of its residents. Including those dummies will deliver a greater explanatory power because they would absorb the idiosyncratic information of each county.

Table 7. Linear probability models of the homeowner and renter

	HOWNER			RENTER		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	MOLD	SMOKE	HLTH_EXVG	MOLD	SMOKE	HLTH_EXVG
WHITE	0.00252	0.0209***	0.0102*	0.0330***	0.0753***	-0.00286
	(0.00654)	(0.00727)	(0.00555)	(0.00814)	(0.00981)	(0.00732)
BLACK	0.0383***	0.0612***	-0.0298***	0.0405***	0.124***	-0.0224***
	(0.00818)	(0.00909)	(0.00766)	(0.00928)	(0.0112)	(0.00856)
LATIN	0.0448*	0.0425	-0.0264	0.0224	0.0574**	-0.0479**
	(0.0233)	(0.0259)	(0.0250)	(0.0211)	(0.0254)	(0.0223)
HSCHOOL	-0.0114***	0.0629***	-0.0534***	-0.00826*	0.0602***	-0.0640***
	(0.00316)	(0.00351)	(0.00332)	(0.00446)	(0.00538)	(0.00433)
LOWINC	0.0194***	0.0403***	-0.0749***	0.0278***	0.0454***	-0.0891***
	(0.00332)	(0.00369)	(0.00348)	(0.00495)	(0.00597)	(0.00425)
HHAGE	-0.000630***	-0.00147***	-0.00450***	-0.000290**	-0.000811***	-0.00655***
	(0.000101)	(0.000112)	(0.000105)	(0.000121)	(0.000146)	(0.000129)
lnUNITSF	-0.00341	-0.0410***	0.0413***	0.00295	-0.0501***	0.0414***
	(0.00283)	(0.00315)	(0.00286)	(0.00374)	(0.00451)	(0.00376)
lnAGEHOUSE	0.0394***	0.0379***	-0.0113***	0.0384***	0.0582***	-0.00168
	(0.00198)	(0.00220)	(0.00178)	(0.00299)	(0.00361)	(0.00268)
lnCSTMNT	0.00365***	-0.000280	-0.00112*			
	(0.000652)	(0.000724)	(0.000641)			
MNTNS				-0.177***	-0.108***	0.0795***
				(0.00518)	(0.00624)	(0.00575)
MOLD			-0.0409***			-0.0440***
			(0.00434)			(0.00561)
SMOKE			-0.0617***			-0.0678***
			(0.00421)			(0.00435)
Constant	0.0605**	0.378***	0.896***	0.147***	0.434***	0.872***
	(0.0245)	(0.0272)	(0.0240)	(0.0312)	(0.0376)	(0.0300)
Observations	57,919	57,919	57,919	35,730	35,730	35,730
R-squared	0.020	0.035	0.102	0.046	0.052	0.134
State-County Ctrl	yes	yes	yes	yes	yes	yes
Bootstrapped	yes	yes	yes	yes	yes	yes

Note. The Linear Probability Model (LPM) is an Ordinary Least Square (OLS) regression where the dependent variable is a binary variable. This model was granted valid in the sense that the intercept of this linear model was positive and significant, which means that the predicted line would not pass any negative values. Models 1, 2, 4, and 5 were Seemingly Unrelated Regressions (SURE) based on the errors of MOLD and SMOKE. Since the MOLD and SMOKE models of each sample used the same home maintenance variable, by sample type, the MOLD and SMOKE models were nested in each other. All models included 77 state-county dummy variables as controls and were bootstrapped with 1,000 iterations.

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

As seen in the previous subsection, since the direct effects in this study are almost equivalent to the total effects, it is sufficient only to test the direct effect models and examine whether it produces a similar output as in the maximum likelihood estimation.

The regression output of the postestimation model is shown in Table 7. Like in the previous estimation models in Table 2, the observation number of the homeowner's samples was 57,919 and 35,730 in the renter's models. The coefficients in Table 7 are interpreted as the percentage change of the dependent variable by an increase of the independent variable.

Almost all the variables are showing a very similar result as in the maximum likelihood estimation in Table 2, with a few variables statistically being a little more or less significant. These differences are ignorable because the identification of these variables was ambiguous in the first place. Also, the change of the significance levels of those variables comes from the different identification approach of extrapolating the data to a linear projection rather than a Normal probability function. However, it is important to go over them once again and confirm the differences between a structural equation model based on a maximum likelihood estimation and the Ordinary Least Square (OLS) prediction.

One of the significant differences in this postestimation model is the variable WHITE in the homeowner's sample. Compared to the output in Table 2, in Model 3, WHITE changes from insignificant in Table 2 to slightly significant in the health regression of Table 7. Similarly, in Model 1, WHITE changes from being a little significant in Table 2 to insignificant in the MOLD regression in Table 7. This change in significance levels indicates that WHITE is better identified in the health regression when applying a linear identification strategy, and better identified in the MOLD estimation when applying a maximum likelihood estimation. This phenomenon shows that by different identification strategies, the significance level can change.

Another variable that shows a change in the level of significance in the homeowner's sample is the lnCSTMNT variable. In Model 3 of Table 2, it showed an insignificant result, yet in the Ordinary Least Square (OLS) model in Table 7, we can observe a slightly significant result. As argued before, lnCSTMNT showed coefficients that revolved around zero and did not deliver meaningful information on the health status of the homeowner. This little change in the postestimation result certainly lets me conclude that the home maintenance effort to intervene poor indoor air quality does not have an integral effect on the health status of the homeowner. However, contrary to this variable output, the MNTNS variable of the renter's sample consistently shows a strong positive outcome. Hence, again, an intervention to improve the housing condition is more effective to the renter than the homeowner.

As for the renter's sample, LATIN now shows a significant relationship with SMOKE, which previously was insignificant in Table 2. Also, previously, in Table 2, LATIN was only significantly correlated with MOLD only, yet now, it is only SMOKE. Thus, based on the comparison between Tables 2 and 7, it is ambiguous to say whether mold or smoke was present in Latin homes.

In sum, in this section, I found that for some variables and samples, a better or worse identification strategy is applied when I apply a linear model. However, even though in some cases they were identified better by a linear regression model, the results showed that the significance level only rose a little bit, while highly significant variables in the previous estimations, continued to deliver a solid result. Thus, the estimation results of the maximum likelihood estimation and the Ordinary Least Square (OLS) regression with bootstrapped standard errors were almost identical.

CHAPTER 4

CONCLUSION

This study explored the health disparities of homeowners and renters who are affected by the poor indoor air quality in their dwellings. By using observations of mold and smoke as a conjoint proxy for poor indoor air quality, I built a mediation path model that tested the mediation effect of poor indoor air quality by homeowners and renters. Grounded in the notion of environmental injustice and the theory of housing adjustment, my mediation model was built on a structural equation model that had variables pertinent to race, socioeconomic status, housing condition, and the intervention effort of the dwelling occupant as exogenous variables that were linked to the endogenous mediation effect of poor indoor air quality and the occupant's health. The originality of this study stresses the empirical novelty of the mediation effect of poor indoor air quality, which has not been scrutinized empirically.

The primary finding of my research specifically shows that the mediation effect of poor indoor air quality differs by homeowner and renter in the sense that the negative health outcome of the renter was greater than that of the homeowner. Consistently, when mediated through poor indoor air quality, all exogenous variables showed a greater deteriorating health effect in the renter's sample as compared to the homeowner. The most prominent and consistent results were found in the variables related to the resident's low-income and low-education status that showed a strong mediated indirect effect, where the renter more experienced environmental injustice than the homeowner. This disparity in health between the homeowner and renter in terms of low income and education was observed consistently throughout all the analyses.

Pertinent to other variables related to environmental injustice in the family and housing dimension, outcomes of race-related variables only showed a consistent health outcome among the African American population. Other demographic variables, such as the age of the household head, showed minimal effect sizes. In the direct and total effect models, the health status of the African American homeowner was worse than the renter. This shows that a mediation model specifies the health disparity between homeowner and renter better than a direct effect estimation. In terms of the age of the resident, even though the total effect showed a more unfavorable health outcome in the renter's sample, the effect of age remained minimal throughout all the analyses.

Regarding the proxies for intervention, it was found that home maintenance profoundly benefited the renter's health, while the effect size of the homeowner remained minimal throughout all stages in the analyses. This result supports the notion of corrective measures in the housing adjustment theory that housing decisions related to home maintenance for a more amiable dwelling environment can be effective. In most of the original work by Morris and Winter (1975), though, home maintenance is ambiguous in terms of whether or not it addresses indoor air quality.

As for the variables related to the housing condition of the resident, it was found that a ten square footage increase in the occupant's dwelling size would almost equally benefit both the homeowner and renter, while the result pertinent to the age of the house remained inconclusive.

Pertaining to suggestions for future research, I submit that future research about environmental injustice should focus more on the endogenous structural effect of environmental hazards related to the socioeconomic background of its residents. Approaches using potentially hazardous environmental substances as instrumental variables of one's socioeconomic background would equip the researcher with a strong argument on how the health of a resident exacerbates, given the unequal living space of the underprivileged population.

CHAPTER 5

DISCUSSION

5.1. Call for mandates

People in modern societies spend more than 90 percent of their time in indoor environments (Wu, Jacobs, Mitchell, Miller, & Karol, 2007). This also shows the gravity of indoor air quality as a public health subject. However, despite its significance, regulating and legislating indoor air quality-related policies remains a hurdle in our society. This difficulty partially originates from the fact that indoor air arrangements encompass private properties such as homes, workplaces, or vehicles that cannot be regulated by federal law unless one imposes an imminent threat to all the occupants. Moreover, the common belief in the United States that, “a man’s home is his castle,” makes it even more difficult to regulate homes due to the notion of freedom. Also, housing codes are enforced only at the local, but not at the federal level. Furthermore, enforcement of regulations and code compliance differs across localities.

The second reason of indoor air quality being a difficult subject to control is that air and the molecular particles that impose a danger to one’s respiratory health are not observable with one’s eyes and that the impact of poor indoor air quality does not immediately show symptoms in the occupant’s health. As Sundell (2004) articulates, issues related to indoor air quality have a “lamppost effect” (p. 55). That is, we investigate matters that are easily detectable (i.e., under the lamppost), but are rather negligent about issues that are ‘in between’ those “lampposts.” This is partially the reason for the insufficient political interest, whereas, for regulations related to smoking, smoking behaviors, as well as the physical smoke, are directly observable.

The third reason for the difficulty of regulating indoor air quality comes from the fact that air is a public good, where the cost of clean air is higher than the benefit. In other words, private investment in clean air expands the beneficiaries to the greater public so that the allocated benefit to this private investor is very small. This is one of the reasons why, unless air is regulated from the public sector, it is difficult to enforce policies related to clean air. Wu, Jacobs, Mitchell, Miller, and Karol (2007) submit that the cost of healthy homes is not included in the market price of the dwelling. The reason for this comes from the ambiguity of the value of indoor air quality as well as the increase in the sales price once the price of clean air is incorporated into the cost of construction, rehabilitation, and maintenance (Jacobs, 2005). Pertaining to the value of healthy homes and clean indoor air quality, the health benefits of an individual are difficult to measure because it is a long-term investment that requires due diligence.

The current practice of improving the health standards of a dwelling occupant is through education and the active participation of an individual. To achieve this goal, public education regarding indoor air should be funded more on a national basis. The lack of interest and unawareness of ambient indoor air quality within a dwelling partially comes from poorly funded public programs that ignore the severity and perils of poor indoor air quality. However, prevention education would not only benefit a resident's health prospects but would also financially benefit the individual in a sense it would tremendously reduce the spending on long-term health issues.

5.2. Interdisciplinary research

Regarding the direction of future research, it should head more to the direction of an inter- and multidisciplinary science where not only research from an engineering or architectural standpoint but also areas in the social science arena can be contemplated. Most of the research about indoor air quality has been elaborated on a natural scientific ground without exploring the social impact. Even in the world's most prestigious academic organization related to indoor air such as the International Society of Indoor Air Quality and Climate, most of the papers that are published are separated by natural and social sciences, yet an interdisciplinary paper is difficult to find. A combination of data from natural and social science areas would enrich the research about the impact of poor indoor air quality in a very systematic and structural way.

One of the limitations that the social science area has is that the actual health status or the air quality is not directly observable in the sample unless it is scientifically measured. Most of the health statuses of the survey respondents remain self-reported and, therefore, does not include actual information about hidden health components affected by poor indoor air quality. As in my study's sample, most of the survey respondents reported an excellent and very good health condition. I only observed the hazards of poor indoor air quality through statistical techniques that have not been tried in the past. Thus, unless one is applying sophisticated measurement techniques, a self-reported health status would not deliver sufficient information about the actual threat of poor indoor air quality.

Another issue that research on indoor air quality faces is the size of the data if the data from the national science sector is combined with data from the social science discipline. It is very difficult to identify every single observation in a sample that combines the molecular atmospheric condition with one's socioeconomic status, partially because of privacy matters. Even when we pursue individual research on a site by scientifically measuring the quality of air in a dwelling and subsequently ask questions related to one's socioeconomic status, such research would only be restricted to small sample sizes at few sites, yet would not represent a nationwide observation. This is partially due to the cost of measuring and conducting interdisciplinary research at a larger scale, which was the customary case in the past. Thus, government-funded projects that support the simultaneous measurement of indoor air quality and socioeconomic status of the resident throughout multiple sites in the country is a noble mission for the future. Only then, the research findings would be able to increase the propensity towards regulations and policies pertinent to indoor air quality.

5.3. About this study

Regarding the findings of this study, the primary argument that my findings make is that environmental injustice related to housing issues should be comprehended in a social context rather than one's biological trait, such as race or age. That is, as exhibited in previous analyses, this paper argues that the problem of poor indoor air quality and the associated health disparities between homeowners and renters can be tracked down to socioeconomic disparities of the residents. The empirical analysis evidently showed that low income and education provide the most consistent cause of the health disparity between the homeowner and renter. Thus, environmental injustice is indeed a social product.

Examining the mediation model from a systematic standpoint, the renter faces several housing norms, including one's tenure status, whereby the renter's health was exacerbated through poor indoor air quality of its dwelling more than the homeowner. In previous studies, this relationship between one's health deterioration and housing norms was only elaborated in a simplistic relationship. However, as emphasized before, the relationship of one's socioeconomic status and health deterioration, given one's tenure status, is more complex. As we have seen in the direct effect model, several variables cannot be sufficiently explained if one does not address the systematic endogenous nature of indoor air quality. As noted by Sundell (2004), indoor air quality is an outcome generated by the shelter itself combined with human activities. In this sense, a health outcome should be addressed in a systematic manner where the relationships among the variables should be identified by a structural combination of various factors.

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APPENDIX

CONCEPTUAL MEDIATION MODEL BY LEVEL OF ANALYSES

Social and physical conditions (Stressors/Resources)	**Housing**	→	**Environmental pollutants**	→	**Health outcome**
Level of analysis			***Level of analysis***		***Level of analysis***
Social/Structural ○ Political forces	*Social/Structural* ○ Historical context ○ Urban renewal ○ Relocation policies	→	*Social/Structural* ○ Community air quality	→	*Social/Structural* ○ Socioeconomic, race/ethnic, and geographic disparities in rates of asthma
Neighborhood ○ Neighborhood income ○ Neighborhood organizational features ○ Human capital (e.g., employment, education) ○ Social capital ○ Social cohesion ○ Ethnic density ○ Integration/Segregation ○ Safety (e.g., police presence, violent crime) ○ Index of dissimilarity ○ In-Out migration	*Neighborhood* ○ Housing values ○ Housing cost as a percentage of average income ○ Housing type: subsidized, private (rent/own) ○ Housing form: cluster, high-rise, brownstone ○ Residential stability ○ Vacancy rate ○ Age of dwelling ○ Utility cutoffs ○ Homelessness rate ○ Housing code violations ○ Building permits ○Tax delinquencies	→	*Neighborhood* ○ Physical toxicants: traffic patterns, bus depots, commercial establishments, waste transfer stations.	→	*Neighborhood* ○ Small area asthma rates by community, census block or housing unit
Individual/Family ○ Disposable income ○ Asset/Wealth ○ Family conflict ○ Role strain ○ Perceived stress ○ Home learning ○ Parenting practices	*Individual/Family* ○ Physical condition of the housing unit ○ Moves / Evictions / Length of residence ○ Rent-to-Income Ratio	→	*Individual/Family* ○ Indoor air quality ○ Outdoor air quality ○ Air exchange ○ Cockroach allergens	→	*Individual/Family* ○ Individual health status ○ Lung functions, wheezing symptoms ○ Asthma diagnosis, asthma-related hospitalizations ○ School absence, self-management

Note. This table is a modified version of the original work by Rauh, Landrigan, and Claudio (2008).