DOI: 10.1111/1540-6229.12317

Check for updates

WILEY

ORIGINAL ARTICLE

The impact of housing conditions on health outcomes

Juan Palacios[1] | **Piet Eichholtz**[2] | **Nils Kok**[2] | **Erdal Aydin**[3]

[1]Massachusetts Institute of Technology, Cambridge, Massachusetts

[2]Maastricht University, Maastricht, The Netherlands

[3]Sabanci University, Istanbul, Turkey

Correspondence
Nils Kok, Department of Finance, Maastricht University, Maastricht, The Netherlands.
Email: n.kok@maastrichtuniversity.nl

Funding information
Dutch National Science Organization (NWO); Nederlandse Organisatie voor Wetenschappelijk Onderzoek, Grant/Award Number: 452-13-004

Abstract

We investigate the relationship between housing conditions and health outcomes using a data set that tracks 25,000 German households over 25 years. We document that individuals exposed to poor housing conditions report worse mental and physical health, and experience an 11% increase in doctor visits, increasing to 20% for age groups over 64. The analysis controls for individual, dwelling, and temporal fixed effects, and is robust to changes in socioeconomic status, lifestyle choices, and neighborhood conditions. As a robustness check, we use home renovations as major a trigger of changes in housing conditions. Restricting the analysis to tenants, whose renovations are paid by landlords, we document that home renovations significantly reduce doctor visits, corroborating the findings on home conditions and health outcomes.

1 | INTRODUCTION

Increasing welfare and longevity, and the corresponding rise in the demand for health services, are confronting modern society with rapidly rising health care costs. Projections of these costs for 2040 are as high as 18.5% of U.S. GDP, 12.7% of German GDP, and 9.6% of U.K. GDP (Dieleman et al., 2017). Understanding the causes of health deprivation, and providing solutions toward prevention, present an increasingly critical challenge for academia, private market participants, and policymakers.

Housing and the built environment play a major role in shaping human health. Historically, inadequate housing has fueled the spread of disease, affected individuals' physical and mental health,

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2020 The Authors. *Real Estate Economics* published by Wiley Periodicals LLC on behalf of American Real Estate and Urban Economics Association

and increased mortality (Rosen, 2015). Slum clearance, sanitation, and provision of affordable housing are just some examples of public health policies enacted in modern history to ensure healthy living conditions (Shaw, 2004). The provision of adequate housing should lead to increased human well-being, and subsequently lower health care costs. Yet, limited evidence exists to support these claims, with the current evidence mainly focused on the health effects of outdoor hazards in the area surrounding homes.

Indeed, the relationship between outdoor environmental issues and human health has been well established in the literature. Numerous studies provide quasi-experimental evidence of the causal link between environmental hazards such as extreme temperatures or air pollution and human health (for a review, see Deschenes, 2014; Zivin & Neidell, 2013). The literature has documented the effects of such external effects on a variety of health outcomes, including mortality rates (Barreca, 2012; Deschênes & Greenstone, 2011; Ebenstein, Fan, Greenstone, He, & Zhou, 2017), infant mortality rates (Currie & Neidell, 2005; Luechinger, 2009), (low) birth weights (Currie, Davis, Greenstone, & Walker, 2015), school absence (Currie, Hanushek, Kahn, Neidell, & Rivkin, 2009), work hours (Hanna & Oliva, 2015), and respiratory and heart-related hospital admissions (Schlenker & Walker, 2016).

However, indoor environmental conditions are not merely a by-product of outdoor environmental conditions, and while there is some research concerning the impact of indoor conditions on human health, such evidence is mainly based on small-scale intervention studies and in settings not typically applicable to the average dwelling in developed economies (Barron & Torero, 2017; Cattaneo, Galiani, Gertler, & Martinez, 2009; Galiani et al., 2017; Imelda, 2018). A recent paper in this literature is Kuenn and Palacios (2017), who analyze the health implications of a large housing renovation program in East Germany that was sponsored by the German government after reunification.[1]

The aim of this paper is to estimate the impact of housing conditions on health outcomes in a setting representative of dwellings in modern societies having a higher-quality housing stock. Research results for housing in that setting is virtually nonexistent. Addressing this knowledge lacuna is important, given that 90% of an individual's time is typically spent indoors (Klepeis et al., 2001). People are working in office buildings, living in their homes, and spending leisure time in shopping malls, restaurants, the gym, and so forth.

Empirically assessing the consequences of deficient housing conditions on human health is challenging. First, large data samples with standardized measures of housing conditions and occupants' health are generally not available. As opposed to relying on small-scale intervention studies, this study takes a different approach to explore the impact of housing conditions on health outcomes, and the subsequent demand for healthcare. The starting point is that household panel data sets and transparent statistical models can complement evidence from the experiment-based medical literature, helping to generalize its results. In order to examine the link between housing conditions and human health, we exploit the German Socio-Economic Panel (GSOEP). Starting in 1984, this data set is, to the best of our knowledge, the longest individual-level data set that provides information on both health and housing conditions (Wagner, Frick, & Schupp, 2007). Each participant is interviewed individually, and asked to evaluate the condition of their dwelling, as well as to complete an extensive questionnaire on

[1]The authors show that in the 1990s, the amenities of houses in the former German Democratic Republic (GDR), based on the poor construction standards of the Soviet block, were upgraded to Western standards. As described by the authors, at the beginning of their sample period 52% of the houses did not have central heating systems and over 26 of the houses lacked an indoor bathtub or shower. These conditions are far from representative of current housing standards in affluent countries, and policy relevance for that type of countries is therefore limited.

subjective health status and on their demand for healthcare, objectively measured by the number of visits to a doctor and the days of sick leave.[2]

Second, since individuals with a higher socioeconomic status presumably live in better maintained dwellings and in low-poverty areas, it is difficult to separately distinguish the effect of housing conditions from the effect of variables comprising the socioeconomic profile of individuals. The participation of individuals in the GSOEP over long periods of time allows researchers to observe the same individual, exposed to varying housing conditions, over the sample period. In our empirical specification, we estimate the impact of housing conditions on health outcomes with individual- and dwelling-fixed effects, exploiting the changes in health outcomes associated with within-individual variation in housing conditions.

Third, one of the most problematic time-varying factor is the set of characteristics of the home. A key instrument to improve housing conditions is moving to a new home. However, the potential improvement in individuals' health might well coincide with improvements in the characteristics of the neighborhood. We introduce individual–dwelling fixed effects to control for time-invariant, unobserved and idiosyncratic characteristics of participant's homes. This way, we exploit variations in individuals' housing conditions over time, while keeping the home address constant, avoiding potential confounding factors associated with moving to a new home (e.g., moving to a healthier home and a healthier neighborhood environment).

Last, there is the important question of self-selection into home renovation. Homeowners decide themselves whether to renovate or not, but for tenants, this decision is made by a landlord and is exogenous to the tenant, so a focus on tenants addresses potential endogeneity biases. In many countries, however, the rental housing sector caters to the poorest parts of society only, compromising the external validity of the findings. Low-quality housing is likely to be occupied by low-income inhabitants who tend to be in poorer health than the population as a whole, making generalization of the findings difficult. But in Germany, over the sample period considered in the analysis, homeownership was about 50%, among the lowest in the world. By specifically analyzing tenants in a German data set, we minimize renovation endogeneity without compromising the external validity of our findings.[3]

The results from the empirical analysis show that the effects of housing conditions on health outcomes are substantial. Those individuals living in dwellings with a poor indoor environment experience an 11% increase in demand for healthcare, as reflected in the number of visits to the doctor. The effects show substantial heterogeneity based on dwelling conditions, and hold across income groups. Moreover, the effects of poor housing conditions on medical service consumption increase with age. Results from our analysis of subjective health measures (the SF-12 questionnaire) suggest that the increase in demand for healthcare is mainly driven by a deterioration of mental health. Interestingly, we do not find a statistically significant relationship between poor housing conditions and days of sick leave from work.

We corroborate our results using an event study around the occurrence of (exogenous) home renovations. We restrict the analysis to tenants, as the decision to renovate a home is made by a landlord, and is thus exogenous to the tenant's health. We document that home renovations significantly reduce doctor visits, confirming the findings on home conditions and health outcomes.

[2]The fact that data are explained and collected by an interviewer rather than an online survey mitigates some of the concern about the subjectivity of one of our variables of interest, the home maintenance condition.

[3]Of course, this assumes that tenants have limited bargaining power over their landlords. Given that 58% of the German rental stock is owned by corporate and public housing companies, violation of this identifying assumption seems implausible—after all, these companies are unlikely to tailor the timing of renovation programs to the specific needs of individual tenants.

Finally, we study avoidance behavior of individuals as it relates to housing conditions. Individuals can avoid or reduce their exposure to poor housing conditions by either moving or by renovating their home. We observe that individuals living in a poorly maintained home have a higher propensity to move, with remarkably similar effects for homeowners versus tenants. However, when investigating renovations, we observe evidence of underinvestment in the rental housing market due to the presence of external effects—landlords have to make investments, which benefit tenants' health rather than generating direct economic outcomes for the landlord. Owner-occupiers living in homes that need a major renovation show a likelihood of about 23% to renovate their home, while the likelihood of home renovation of poorly maintained rental homes is less than 5%, prolonging tenants' exposure to unhealthy housing conditions.

In the remainder of this paper, we first describe the existing literature assessing the impact of housing conditions on individuals' health. In Section 3, we describe the data sources and provide some descriptive statistics. In Section 4, we present the methodology, and specifically discuss issues of causality and identification. In Section 5, the results of the empirical analysis are provided. The paper ends with conclusions and policy implications.

2 | LITERATURE

Economists often approach health using the theoretical model of Grossman (1972), where individuals are born with a stock of health capital that depreciates over the years and increases through different health investments, such as sports. An adult's health is the main determinant of the number of days that an individual is productive in the labor market and, in turn, able to work and to earn income. Over the past decades, scholars have made a persistent effort on the identification of different factors affecting the rate of health depreciation and the demand for health investments.

The literature on health economics has documented the relationship between different aspects of individuals' living conditions and their health status in multiple domains. In the socioeconomic domain, studies using self-reported health indicators from different countries such as the United States, the United Kingdom, or Germany show a direct relation between household income and the health conditions of individuals (Adams, Hurd, McFadden, Merrill, & Ribeiro, 2003; Contoyannis, Jones, & Rice, 2004; Frijters, Haisken-DeNew, & Shields, 2005). Long-term evidence from the often-cited field experiment Moving to Opportunity shows that participants who moved from low-income neighborhoods to less distressed areas subsequently had a measurably improved physical and mental health and well-being status (Ludwig et al., 2012).

The impact of the living environment on individuals' health is not limited to socioeconomic channels. The literature has shown the detrimental effects of different environmental hazards on health outcomes. In particular, a number of studies document the relation between high levels of air pollutants (e.g., ozone or carbon monoxide) and increases in respiratory and heart-related emergency room admissions (Schlenker & Walker, 2016), low birth weight (Currie et al., 2015), and higher school absences (Currie et al., 2009).

The existing studies regarding the exposure of individuals to environmental hazards commonly rely on outdoor measurements (e.g., Currie, 2009; Currie et al., 2015; Deschênes & Greenstone, 2011). However, while the indoor conditions of homes are a function of outdoor conditions surrounding the dwellings, they are not determined by outdoor conditions alone. Individuals can take multiple actions against outdoor environmental hazards to mitigate their exposure. One of the most common examples is to adjust the heating or cooling to avoid exposure to extreme temperatures. Deschênes and Greenstone (2011) document the presence of such avoidance behavior under extreme temperatures in the United

States between 1968 and 2002, where extreme outdoor temperatures systematically preceded peaks in both mortality rates and energy consumption.

Although people in developed economies spend, on average, 90% of their time indoors, not much is known about the impact of buildings on health outcomes. The existing knowledge regarding the impact of the indoor environment on health comes mostly from the medical literature and is based on small-scale experiments or cross-sectional surveys. An example is a pan-European housing and health survey that involves inspections of dwellings by trained surveyors (WHO, 2007). The results suggest that people living in homes with poor conditions (e.g., bad lighting and ventilation, presence of noise, etc.) systematically reported a higher number of mental and respiratory health problems. However, these results are solely based on cross-sectional analysis and therefore do not shed much light on the causal effects that housing conditions may have on health outcomes.

Intervention studies allow researchers to isolate biological impacts, but generalization of their results tends to be limited by small sample sizes and the unique characteristics of the participants. Indeed, reviewing the experimental medical literature studies published between 1887 and 2007 in different Western countries, Thomson, Thomas, Sellstrom, and Petticrew (2009) address the need for large-sample studies using micro data, to better estimate dose–response functions and the potential for improvements of the housing stock.

A third strand of literature on indoor conditions and health outcomes is based on quasi-experimental studies that involve policy interventions in slums or developing countries, where sociodemographic characteristics differ fundamentally from those of the average household in the United States or European Union. For example, Cattaneo et al. (2009) study the effect of replacing dirt floors with cement flooring. This intervention produced significant improvements in occupants' health, measured by reductions in the number of respiratory problems and allergies. Barron and Torero (2017) explore the implications of a randomized controlled trial in El Salvador, where households were granted discount vouchers to connect to the electricity grid. The estimation results show significant drops in respiratory infections among children, associated with a decrease in $PM_{2.5}$ after connecting the dwellings to the grid. Galiani et al. (2017) report significant improvements in children's health followed by the provision of prefabricated houses to slum dwellers in Latin America. Coal cooking stoves are another major source of indoor air pollution in the developing world. Smith-Sivertsen et al. (2009) document significant improvements in lung function and a reduction in respiratory symptoms followed by the provision of upgraded cooking stoves in Guatemala, but Hanna, Duflo, and Greenstone (2016) found no effects in a similar intervention in India. However, it remains an open question whether dwelling conditions also have such significant health effects when the baseline quality of housing is quite good already, as will likely be the case in developed countries.

3 | DATA AND DESCRIPTIVE STATISTICS

In order to identify the relationship between housing conditions and health outcomes, we benefit from a large, longitudinal data set containing information on both housing conditions and occupant health status, as well as other household characteristics that are likely to affect health outcomes. The GSOEP, v31, provides a panel data set, with annual information on individual health and housing conditions since 1984, covering more than 20,000 individuals and 11,000 households at any given time (Wagner et al., 2007). The longitudinal nature of the data set enables us to control for unobserved individual characteristics, by focusing on the relationship between the overtime variation in housing conditions and the health situation of individuals. In addition, the survey includes extensive information on tenure

choice, socioeconomic and demographic characteristics of individuals, their health status, as well as detailed information about living conditions.

We use the data from all available waves for West Germany after re-unification, covering the period from 1990 through 2014.[4] Our full sample includes 57,581 adults (30,151 women and 27,430 men) and a total of 24,849 households. The average duration that an individual is included in the survey is 6.48 years (standard deviation = 5.27), with a maximum of 23 years.

3.1 | Health outcomes

The GSOEP provides information on several health metrics. In this paper, we focus on three different health outcomes to establish the link between housing conditions and health: (a) health status, (b) health care utilization, and (c) health behavior.

With respect to health status, we use the Mental and Physical Component Summary Scales. These scales are widely used in the economic literature to explore detrimental effect of different hazardous events (e.g., Eibich, 2015; Marcus, 2013; Schiele & Schmitz, 2016). The measures are constructed based on the answers of participants to the health SF-12 questionnaire. This questionnaire is included in the GSOEP every 2 years since 2002, and contains 12 different questions about the mental and the physical health status of respondents in the 4 weeks preceding the interview (e.g., "How often did you have strong physical pains in the last 4 weeks?"). The mental and physical scales are constructed based on factor analysis, ranging from 0 to 100 (with higher values denoting a better health status).[5]

In addition to mental and physical health, we also include individuals' self-assessed health status over the last year (on a five-point Likert scale).[6] This question is included in the GSOEP for every wave since 1992, except for 1993. Self-assessed health measures are commonly used in empirical studies to explore the dynamics of health in a given population of interest (Contoyannis et al., 2004), or to estimate the damaging effect of different aspects of living conditions (Bilger & Carrieri, 2013; Frijters et al., 2005). We construct a measure of bad health status from this five-point Likert scale that takes the value of one if the individual reports being in bad or poor health, and zero otherwise.

We use the number of visits to a doctor as a quantitative measure of health care utilization. Participants are asked to report the number of times they visited their general practitioner in the last 3 months. This measure is widely used in the literature to explore the demand for healthcare (e.g., Pohlmeier & Ulrich, 1995; Santos Silva & Windmeijer, 2001; Winkelmann, 2004). The survey included this question in every wave since 1991, except for 1993 and 1994. We explore the effect of housing conditions on health care utilization based on two measures: (a) visiting the doctor at least once during the past three months (yes/no), and (b) the number of doctor visits in the last 3 months. We also explore the days on sick leave reported over the last year.

Finally, we use the body mass index (BMI) and whether people smoke as measures of health behavior. "Good health behavior" refers to the different activities undertaken by individuals to maintain or improve their health status, or to prevent illness. Typical examples include exercise, (quitting) smoking, or (healthy) nutrition. In the literature of health economics, the BMI and smoking are often used to capture the effect of health behavior on health status (Künn-Nelen, 2016; Reinhold & Jürges, 2010).

[4]While the GSOEP starts in 1984, the current health status is not incorporated until the beginning of our sample period.

[5]A detailed description of the construction of the scales is provided by Andersen, Mühlbacher, Nübling, Schupp, and Wagner (2007).

[6]Every year, participants are asked to assess their "current health" as: "very good," "good," "satisfactory," "poor," or "bad."

3.2 | Housing conditions

We evaluate the condition of participants' dwellings based on self-assessment by the individuals. Each year, all survey participants are asked the following question: "How would you characterize the condition of the house in which you live? Is it in good condition, in need of partial renovation, or in need of complete renovation?."[7] Based on the answer provided to this question, we categorized each dwelling in the sample as (a) in good condition, (b) in need of minor renovation or (c) in need of full renovation.[8]

Out of the 56,459 survey participants for whom the information on housing conditions is available, 28,635 participants lived at least 1 year in a house in need of a minor renovation, and 4,856 participants lived at least 1 year in a home in need of a major renovation. Those individuals who report living in a house in need of repairs experience between 2 and 3 years of deficient housing conditions, on average. Our estimation strategy focuses on those participants that experience deficient housing conditions for a part of the period in which they appear in the survey. In addition, each year SOEP participants report the advent of a major house renovation in the year preceding the date of the interview.

3.3 | Sociodemographic characteristics

In the analysis, we control for the following sociodemographic characteristics: age, household composition, household income, marital status, employment status (whether the individual is working or not, and whether there was a significant change in his/her occupational status in the year of the survey), education (based on number of years of education and whether the individual holds a college degree), and gender. These variables are commonly used in the literature as determinants of health outcomes, sick leave, and demand for healthcare (e.g., Adams et al., 2003; Contoyannis et al., 2004; Currie et al., 2009). In addition, we also have information about the ratio of household members to the number of rooms in the house and whether the household owns or rents the home. The latter is important for our identification strategy: while the rental housing market in some countries caters only to the poor, this is not the case in Germany. Renting a home is common in Germany, also for relatively well-off citizens. The German homeownership rate is currently just 51.9%, among the lowest in the world.

3.4 | Descriptive statistics

Table 1 provides summary statistics. The average scales on mental and physical health are very close to 50, out of a maximum scale of 100, and the average current health status is 2.57, on a scale of 1 to 5. Of all participants, 25% report bad health. Participants report an average of 5.5 days of sick leave per year and report an average of 2.6 doctor visits in the 3 months preceding the survey.

Regarding dwelling conditions, 54% of participants always report that their home is in good condition, while 39 and 7% report the need for a partial or major renovation in their homes for at least one of the survey years, respectively.

We first compare average health outcomes based on different housing condition categories, using some simple visualizations. As illustrated in Figure 1, individuals living in homes in need of partial or full renovation systematically report poorer health status, no matter which health criterion we consider.

[7] As indicated before, data are collected by an interviewer rather than an online survey, which mitigates some of the concern about the subjectivity of the home maintenance condition.

[8] In the original question in the GSOEP, respondents have an additional option: "Ready for demolition." However, given the low number of responses in that category we decided to omit this option in the analysis, and these observations are removed from the sample.

TABLE 1 Descriptive statistics

	Mean	Std. Dev
Health measures		
MCS: Summary Scale Mental (NBS)	50.38	10.03
PCS: Summary Scale Physical (NBS)	49.75	10.02
Current health status	2.57	0.97
Bad/Poor health (1 = Yes)	0.25	0.43
Visits to the doctor during the last 3 months	2.60	4.30
Number of days out sick (per year)	5.51	20.76
Dwelling characteristics		
Housing condition		
In good condition (1 = Yes)	0.71	0.46
In need of partial renovation (1 = Yes)	0.27	0.44
In need of major renovation (1 = Yes)	0.02	0.15
Number of years in bad condition	3.69	4.75
Size (in m^2)	106.12	47.02
Number of rooms larger than 6 m^2	4.2	1.91
Construction year	1969	24.39
Amount of rent minus heating costs (monthly, in euros)	467.82	238
Household characteristics		
Monthly household net income (in euros)	2,713.11	1,964.13
Individual is a tenant or subtenant (1 = Yes)	0.48	0.50
Ratio household members per room	0.75	0.44
Household typology		
1-Pers.-HH (1 = Yes)	0.15	0.36
Couple without children (1 = Yes)	0.30	0.46
Single parent (1 = Yes)	0.06	0.25
Couple with children younger than 16 years (1 = Yes)	0.23	0.42
Couple with children older than 16 years (1 = Yes)	0.14	0.35
Couple with children younger and older than 16 years (1 = Yes)	0.08	0.27
Multiple generation household (1 = Yes)	0.02	0.14
Respondent characteristics		
Age of respondent	46.21	17.41
Individual is working (1 = Yes)	0.59	0.49
Actual work time per week (in hours)	21.64	21.07
Amount of education or training (in years)	11.84	2.73
Individual holds a college degree (1 = Yes)	0.17	0.38

Note. Mental scale and physical scale health variables range from 0 to 100. "Current health status" variable ranges from 1 (very good) to 5 (bad). "Satisfaction with health status" variable ranges from 0 (very unhappy) to 10 (very happy). The summary statistics displayed above consider the full sample period (from 1990 to 2014), and include 357,353 observations (and 57,581 individuals).

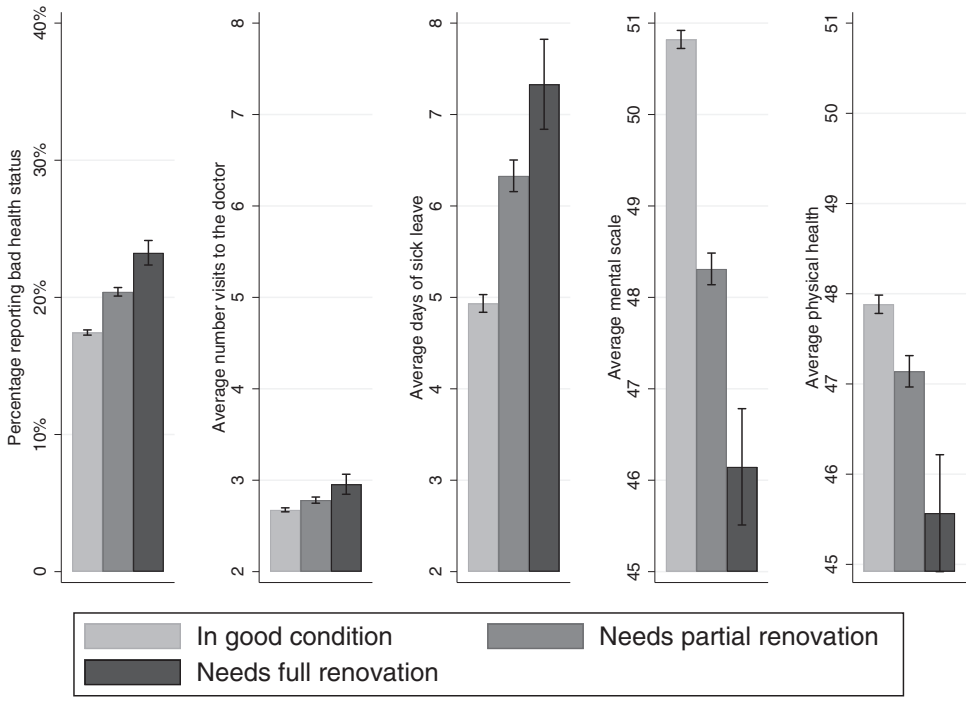


FIGURE 1 Housing conditions and occupant health

Note. This figure presents the average level of health measures for different housing conditions as well as the 95% confidence interval. Current health ranges from 1 (very good health) to 5 (bad health). The three measures are available for all years in our sample (1990–2014). Mental and physical scales range from 0 to 100 (available for survey waves 2002, 2004, 2006, 2008, 2010, 2012, and 2014).

The detrimental effect of poor housing conditions is also reflected in the physical and mental scales, as those individuals living in poor housing conditions report significantly lower values on the physical indicators and especially on the mental scale. Moreover, individuals in poorly maintained homes report a significantly higher number of visits to the doctor in the 3 months preceding the date of the survey, as well as more days of sick leave. Participants living in dwellings in good condition report about 2.5 doctor visits and take about 5 days of sick leave, compared to more than three visits and 7 days of sick leave for those living in a home that needs a full renovation.

Of course, these nonparametric comparisons do not take into account the fact that not every participant in the sample has the same probability of experiencing poor housing conditions. Table 2 shows systematic differences between individuals living in good housing conditions and those inhabiting homes in need of partial or full renovation. Participants living in homes with deficiencies report lower levels of income, are younger, and are more likely to be tenants rather than home-owners.

Thus, the relationship between health and housing conditions could be driven merely by socioeconomic factors that determine both dwelling choice and health, which would affect our inferences regarding the association between housing conditions and health. In particular, previous empirical studies show that income is one of the main factors shaping the demand for health services (e.g., Frijters et al., 2005). Furthermore, those individuals with larger financial means are expected to inhabit better homes, so the apparent relations documented in Figure 1 might be determined by differences in socioeconomic status. Another potential confounding variable is tenure status. Poorer people are more

TABLE 2 Household and dwelling characteristics per dwelling condition

	(1) Dwelling in good conditions	(2) Dwelling in need of minor renovation	(3) Dwelling in need of major renovation
Monthly household income (in €)	2,858.13	2,432.63	1,978.54
	(2,118.04)	(1,521.8)	(1,165.53)
Age of respondent	47.15	44.04	42.22
	(17.57)	(16.75)	(16.31)
Number of rooms	4.31	3.98	3.57
	(1.9)	(1.79)	(2.35)
Dwelling size (in m^2)	110.52	97.05	83.85
	(48.14)	(42.45)	(37.55)
Construction year	1973.14	1960.95	1954.86
	(23.51)	(24.25)	(24.22)
Value dwelling (in euros)	126,417	71,006.8	37,833.23
	(189,752)	(131,674)	(112,993)
Monthly rent (in euros)	486.11	447.04	396.96
	(253.86)	(216.43)	(196.92)
Tenant (1 = Yes)	0.42	0.62	0.82
Dwelling type			
1-2 Family house	0.37	0.29	0.19
1-2 Family rowhouse	0.20	0.16	0.11
Apt. in 3-4 unit bldg.	0.1 0	0.14	0.19
Apt. in 5-8 unit bldg.	0.18	0.22	0.29
Apt. in 9+ unit bldg.	0.10	0.13	0.15
High-rise	0.01	0.02	0.03
Other building	0.00	0.00	0.01

Note. This table reports the descriptive statistics separated for different housing conditions. Standard deviations are reported in parentheses. Information on "Value dwelling" is only available for 2002, 2007, and 2012.

likely to live in rental housing, which tends to be maintained poorly compared to owner-occupied housing (Pollack, von dem Knesebeck, & Siegrist, 2004).

Table 3 provides further insight into the relation between health and housing conditions for different income and age groups, by quartile, and for owner-occupiers and tenants. Panels A through E provide the five different health indicators: bad health status, mental health scale, physical health scale, doctor visits, and days of sick leave. As expected, the statistics indicate that higher income, lower age, and homeownership are all associated with better health outcomes. However, the descriptive statistics also show that the detrimental health effect of poor housing conditions holds within almost any age or income group in the sample, and likewise for homeowners and tenants, no matter how health is measured. Interestingly, the statistics reported in Table 3 suggest that the relationship between poor housing quality and health status is stronger for older and lower-income respondents as compared to higher paid and younger people.

TABLE 3 Housing conditions and health outcomes

	Household net income				Respondent age				Tenancy status	
	First quartile (low)	Second quartile	Third quartile	Fourth quartile (high)	First quartile (young)	Second quartile	Third quartile	Fourth quartile (old)	Owner-occupied	Rental home
Panel A. Proportion of people reporting bad health status by housing condition for different age, income, and tenure groups										
In good condition	0.27	0.20	0.16	0.12	0.12	0.12	0.19	0.29	0.17	0.20
Needs partial renovation	0.29	0.22	0.19	0.15	0.14	0.16	0.26	0.38	0.21	0.23
Needs full renovation	0.33	0.28	0.20	0.18	0.17	0.22	0.37	0.47	0.29	0.28
Panel B. Mental health status by housing condition for different age, income, and tenure groups										
In good condition	49.66	50.73	51.08	51.99	50.23	49.91	50.82	52.49	51.49	50.42
Need partial renovation	47.52	48.98	49.03	49.78	48.49	47.91	48.82	49.92	48.98	48.67
Need full renovation	45.06	47.45	49.3	49.38	47.69	47.15	45.34	46.94	46.88	46.85
Panel C. Physical health status by housing condition for different age, income, and tenure groups										
In good condition	47.13	48.66	50.35	52.14	56.02	53.34	49.71	43.64	49.99	49.96
Need partial renovation	47.28	48.77	50.01	51.38	55.25	51.93	47.98	41.84	49.15	49.46
Need full renovation	45.39	49.08	50.92	52.13	54.63	51.34	46.07	39.59	48.41	47.75
Panel D. Quarterly visits to doctor by housing condition for different age, income, and tenure groups										
In good condition	3.07	2.67	2.41	2.18	1.82	2.01	2.6	3.58	2.46	2.64
Needs partial renovation	3.05	2.70	2.55	2.42	1.97	2.24	3.01	4.00	2.63	2.76
Needs full renovation	3.38	2.88	2.76	2.16	2.10	2.44	3.47	4.94	3.22	2.97
Panel E. Days of sick leave by housing condition for different age, income, and tenure groups										
In good condition	4.70	5.53	5.78	4.68	4.69	6.06	8.42	1.68	4.49	5.92
Needs partial renovation	5.92	6.8	7.16	5.82	5.49	7.45	9.82	2.26	5.64	6.85
Needs full renovation	6.66	7.62	8.31	5.77	5.4	9.28	9.86	2.87	5.29	7.41

4 | EMPIRICAL STRATEGY

The associations between housing conditions and health outcomes are manifold and complex, and an empirical analysis requires the consideration of numerous confounding factors. Investment decisions in health and individual preferences for dwellings are driven by a set of observable and unobservable household and individual characteristics. Furthermore, both are likely to be determined by some common circumstances, possibly biasing the estimated effect of housing conditions on health.

In order to identify the impact of housing conditions on individuals' health, we propose the following reduced-form empirical model:

$$Health^{*}_{i,d,t} = \beta Housing\_Conditions_{d,t} + \lambda X_{i,t} + \delta Z_{d,t} + \alpha_i + t_t + \epsilon_{i,d,t}, \quad (1)$$

where $Health^{*}_{i,d,t}$ denotes the health status of individual i, living in dwelling d, in year t. The health status of individuals will be measured by the health outcomes described in the previous section. $Housing\ conditions_{d,t}$ represents the conditions of the dwelling d at time t. The vector $Housing\ conditions_{d,t}$ includes two dummy variables, one of them taking the value of one if the dwelling needs a partial renovation, and zero otherwise, and the other dummy taking the value of one if the dwelling is in need of a full renovation, and zero otherwise. The vectors $X_{i,t}$ and $Z_{d,t}$ include all the individual and dwelling control variables, respectively. The unobserved component of the model includes the time-invariant idiosyncratic effects, α_i, time (year) fixed effects, t_t, and a normally distributed error term, $\epsilon_{i,d,t}$. Based on this model, the parameters of interest, elements of β, represent the effect of dwelling conditions on the health outcomes of individuals.

As discussed earlier, estimating the causal link between dwelling conditions and occupant health is methodologically challenging. The literature acknowledges the existence of multiple confounders, or variables affecting both the preferences of an individual for the dwelling and his investments in health. The presence of such unobserved factors hinders the proper estimation of the link between dwelling conditions and health using a cross-sectional analysis. We therefore employ the longitudinal nature of our data set to alleviate concerns about potential endogeneity issues.

First, the overtime variation in the data allows for the estimation of fixed-effects models in which the unobserved time-invariant characteristics of individuals can be properly controlled for. The individual-fixed effect approach estimates the impact of poor housing conditions on occupant health based on the variation in housing conditions over time for the same individual.

However, individual-fixed effects alone will likely not be sufficient to control for all unobservables, as the overtime variation in housing conditions can originate from either moving to a new house or from a change in the conditions of the existing dwelling. It is well established in the literature that the environmental and socioeconomic conditions of the neighborhood affect human health through channels like crime or pollution (Bilger & Carrieri, 2013; Ludwig et al., 2012). In order to isolate the impact of housing conditions on health from any neighborhood confounder, we therefore implement an individual–dwelling fixed effect analysis where we exploit the variation in individuals' housing conditions within a specific dwelling. We construct an individual–dwelling identifier by combining the personal identifier of each respondent and the date the respondent moved to the current dwelling.[9] So the fixed-effects strategy we employ controls for both personal and dwelling time-invariant characteristics in the estimations. In effect, the simultaneous inclusion of both types of fixed effects implies that we follow the same inhabitants of the same dwellings through time.

[9]The GSOEP contains information about the exact moving date for each respondent in the sample.

A further concern in the estimations is the self-selection into home renovations. It is possible, for example, that less healthy individuals underinvest in home renovation, or that individuals facing an adverse health shock simply have fewer resources for home maintenance. However, that would only be an issue for homeowners, and not for tenants. In rental housing, maintenance and renovation decisions are taken by the landlord, and are exogenous to the tenant's health status.[10] Our initial analysis focuses specifically on respondents in rental homes. Germany's housing market is characterized by a relatively dominant position of rental homes, mostly owned by institutional housing providers. Indeed, approximately 50% of the GSOEP participants are tenants. That means renting a home is not limited to the lower social strata of German society. In many other countries, renting is limited to the lower-income parts of society, involving low-quality housing and inhabitants who would likely be less healthy than the population as a whole. This would make it hard to generalize the findings. Our focus on Germany addresses these concerns.

As a final check on the role of potential confounders that may simultaneously affect housing choice and health outcomes, we test for the confounding role of health behavior channels. In particular, we consider the effect of the BMI and smoking behavior of respondents. The BMI is widely used as an indicator of health investments by individuals (e.g., Künn-Nelen, 2016; Reinhold & Jürges, 2010), and it is closely related to individuals' nutrition and lifestyle. Smoking is an often-used indicator of an unhealthy lifestyle choices (Cutler & Glaeser, 2005). These two measures serve as indicators of health preferences and potential changes in individuals' budget constraints, not captured by our other controls. We test whether these measures are related to housing conditions. If not, we can conclude that their role as a possible confounding factor is limited, providing more confidence in the direct relationship between housing conditions and health outcomes.

5 | RESULTS

5.1 | Effects of dwelling conditions on health outcomes

We first estimate the model specified in Equation (1) using pooled Ordinary Least Squares (OLS) estimation technique to investigate whether housing conditions affect subjective health status, using the "bad health" perception indicator, the mental health scale, and the physical health scale as dependent variables. The OLS estimation results are reported in Table 4, columns (1), (4), and (7). For each of the health indicators, we document that individuals living in homes in need of renovation report a significantly deteriorated health status. The effect is significantly stronger for dwellings that need a major renovation as compared to dwellings that need a partial renovation.

We include dwelling–individual fixed effects in order to ensure that the overtime variation in health status is not influenced by unobserved characteristics of individuals, dwellings, or a change of neighborhood. The fixed-effect results are reported in columns (2), (5), and (8) of Table 4. We document that individuals living in a home that is in need of partial renovation are 1.1% more likely to report bad or poor health in a given year, and that these individuals obtained an 0.8% and 1.7% lower score on the mental and physical scales, respectively. The detrimental effect on health for those individuals living in a home in need of a major renovation is significantly stronger. Those individuals living in poorly

[10]Germany has very strict privacy laws, so landlords do not know about personal issues, like the frequency with which their tenants visit the doctor. To test whether the timing of renovation is indeed exogenous to tenants' health, we investigate whether the different aspects of health status affect the likelihood of dwelling renovation by the landlord. The results, depicted in Table A1 in the Appendix, clearly show that none of the health aspects employed in this paper (bad health status, mental health, physical health, and doctor visits) is significantly related to subsequent renovation likelihood.

TABLE 4 Estimation results housing conditions on subjective health status

	(1) Bad health (1 = Yes)	(2) Bad health (1 = Yes)	(3) Bad health (1 = Yes)	(4) Log of physical health	(5) Log of physical health	(6) Log of physical health	(7) Log of mental health	(8) Log of mental health	(9) Log of mental health
Housing condition									
Needs partial renovation	0.023***	0.011***	0.007**	−0.018***	−0.008***	−0.004	−0.033***	−0.017***	−0.017***
(1 = Yes)	[0.002]	[0.002]	[0.003]	[0.002]	[0.002]	[0.003]	[0.002]	[0.003]	[0.004]
Needs major renovation	0.048***	0.027***	0.019***	−0.038***	−0.023***	−0.018*	−0.073***	−0.036***	−0.040***
(1 = Yes)	[0.005]	[0.006]	[0.007]	[0.006]	[0.008]	[0.010]	[0.008]	[0.011]	[0.013]
Age of respondent	−0.000	−0.049***	−0.049***	−0.003***	0.002*	0.001	0.000	0.005***	0.002
	[0.000]	[0.001]	[0.002]	[0.000]	[0.001]	[0.002]	[0.000]	[0.001]	[0.002]
Log of monthly income	−0.037***	−0.014***	−0.022***	0.025***	0.003	0.008	0.034***	0.018***	0.028***
	[0.002]	[0.003]	[0.005]	[0.002]	[0.003]	[0.005]	[0.003]	[0.004]	[0.007]
Individual is working	−0.031***	−0.008***	−0.014***	0.024***	0.007***	0.008*	0.007***	0.002	0.021***
(1 = Yes)	[0.002]	[0.003]	[0.004]	[0.002]	[0.003]	[0.005]	[0.003]	[0.003]	[0.006]
Years of education	−0.008***	−0.000	−0.000	0.009***	−0.003	0.001	−0.001	0.000	0.010
	[0.001]	[0.002]	[0.003]	[0.001]	[0.002]	[0.004]	[0.001]	[0.003]	[0.007]
Number of observations	298,675	298,675	143,837	81,612	81,612	35,176	81,611	81,611	35,175
Number of individuals	67,589	67,589	41,404	33,779	33,779	17,626	33,779	33,779	17,626
Mean dependent var.	0.236	0.236	0.261	3.882	3.882	3.884	3.895	3.895	3.877
Year-fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sociodemographic controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Individual-fixed effects	NO	YES	YES	NO	YES	YES	NO	YES	YES
Dwelling-fixed effects	NO	YES	YES	NO	YES	YES	NO	YES	YES
Sample restrict. tenants	NO	NO	YES	NO	NO	YES	NO	NO	YES

Note. Coefficients for year-fixed effects and sociodemographic controls are not reported due to space limitations (available upon request). Heteroskedasticity-robust standard errors are reported in brackets. Standard errors are clustered at household level.

*$p < .10$; **$p < .05$; ***$p < .01$.

maintained homes are 2.7% more likely to report a bad or poor health status, score 2.3% lower on the mental scale, and 3.7% lower on the physical scale, during those years that their homes were in need of a major renovation. The estimation results thus suggest that, on average, those who experience problems with their dwellings are less healthy. Based on all model specifications and all subjective health measures included in the analysis, exposure to homes that are anything less than well-maintained is related to deteriorated health outcomes.

In columns (3), (6), and (9) of Table 4, we restrict the estimation to the tenants in the sample, to address endogeneity concerns regarding the renovation decision. The empirical results remain robust, with coefficients comparable to those reported before. Tenants whose home needs renovation are less healthy, both physically and mentally.[11]

5.2 | Dwelling conditions and economic outcomes

We then examine the impact of housing conditions on health care utilization—as measured by the number of doctor visits—and on absence from work. We investigate the impact of housing conditions and demand for healthcare on both the intensive and the extensive margin. Given the character of visits to the general practitioner, we explore the effect of housing conditions on whether an individual visits the doctor at all, as well as on the total number of visits. As before, columns (1), (4), and (7) present outcomes of the pooled OLS analysis, and columns (2), (5), and (8) show the results of the fixed-effect analysis. Columns (1), (2), and (3) of Table 5 indicate that there is no significant effect of housing conditions on the extensive margin, that is, the likelihood of going to the doctor in the first place. But when investigating the intensive margin, columns (4), (5), and (6) of Table 5, the estimation results show that living in a home in need of partial renovation is associated with an increase of 4.35% (0.060/2.612) in doctor visits, as compared to living in well-maintained homes. These differences are even larger for those living in a home in need of a major renovation, leading to an 11.2% increase in visits to the doctor in the 3 months preceding the survey interview, as compared to living in a dwelling that is in good condition. The results for the tenant sample, presented in columns (3), (6), and (9), are consistent with those in the full sample.

Table 5 also reports results regarding absence from work. We find some evidence of a relationship between dwelling conditions and sick leave when employing the OLS specification, but when estimating the full model that takes into account unobserved individual- and dwelling-specific characteristics, we find no statistically significant effect. Thus, the economic costs of poor housing conditions seem to translate mostly in an increase in demand for healthcare, as reflected by the increase in number of visits to the doctor, rather than absence from work. However, the insignificant effect on presence at work does not imply that productivity, a critical factor for employers, is unaffected by poor housing conditions.

5.3 | Heterogenous effects

This subsection further analyzes the potential heterogeneity in the impact of housing conditions on occupant health. In particular, we explore the role of age as mediating channel between housing conditions and health outcomes.[12]

[11] We control for household income, marital status, and employment status in the regressions, but is may be possible that housing conditions would reversely affect household income, leading to endogeneity biases. In order to confirm robustness, we have done our main regression without controlling for tenancy status, household income, and employment status. This does not markedly affect the coefficients for our variables of interest, that is, those concerning renovation status.

[12] We find no evidence of heterogeneous effects in the detrimental impact of inadequate housing conditions on health outcomes relative to gender and income groups. While the descriptive statistics show that lower-income groups are more likely to be

TABLE 5 Estimation results housing condition and demand for healthcare

	(1) Visit doctor (1 = Yes)	(2) Visit doctor (1 = Yes)	(3) Visit doctor (1 = Yes)	(4) Visits doctor (Number)	(5) Visits doctor (Number)	(6) Visits doctor (Number)	(7) Days on sick leave	(8) Days on sick leave	(9) Days on sick leave
Housing condition									
Needs partial renovation	−0.015***	−0.002	0.002	0.223***	0.060**	0.050	0.916***	0.125	0.172
(1 = Yes)	[0.003]	[0.003]	[0.004]	[0.031]	[0.030]	[0.044]	[0.129]	[0.162]	[0.215]
Needs major renovation	−0.010	−0.007	−0.003	0.452***	0.293***	0.228**	1.387***	0.205	0.000
(1 = Yes)	[0.009]	[0.008]	[0.010]	[0.121]	[0.095]	[0.110]	[0.389]	[0.464]	[0.556]
Age of respondent	−0.001**	0.007***	0.006***	0.049***	−0.042***	−0.036*	0.503***	0.228***	0.191**
	[0.000]	[0.001]	[0.002]	[0.006]	[0.012]	[0.020]	[0.018]	[0.054]	[0.089]
Log of monthly income	−0.002	0.007*	0.009	−0.142***	−0.117***	−0.054	−0.197	0.180	−0.073
	[0.004]	[0.004]	[0.006]	[0.040]	[0.043]	[0.065]	[0.128]	[0.218]	[0.355]
Individual is working	0.047***	0.023***	0.017***	−0.775***	−0.332***	−0.383***	4.460***	2.177***	1.967***
(1 = Yes)	[0.003]	[0.003]	[0.005]	[0.040]	[0.040]	[0.061]	[0.137]	[0.259]	[0.401]
Years of education	−0.006***	−0.001	−0.001	0.004	0.009	0.013	−0.302***	−0.002	−0.059
	[0.001]	[0.002]	[0.003]	[0.010]	[0.021]	[0.033]	[0.036]	[0.101]	[0.158]
Observations	279,700	279,700	132,227	272,130	272,130	127,710	276,653	276,653	131,143
Mean dependent var.	0.309	0.309	0.309	2.612	2.612	2.612	5.490	5.490	5.490
Number of individuals	62,734	62,734	37,662	62,281	62,281	37,275	65,740	65,740	39,995
Year-fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sociodemographic controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Individual-fixed effects	NO	YES	YES	NO	YES	YES	NO	YES	YES
Dwelling-fixed effects	NO	YES	YES	NO	YES	YES	NO	YES	YES
Sample restrict. tenants	NO	NO	YES	NO	NO	YES	NO	NO	YES

TABLE 6 Heterogeneous effects by age group

Panel A. Visits to the doctor					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Doctor visits	**Doctor visits**	**Doctor visits**	**Doctor visits**	**Doctor visits**
	Age 18–30	**Age 31–40**	**Age 41–50**	**Age 51–63**	**Age >64**
Needs partial renovation	−0.123	0.043	0.018	0.146	0.240***
(1 = Yes)	[0.088]	[0.103]	[0.088]	[0.100]	[0.091]
Needs for major renovation	0.102	0.524*	0.567*	0.468	0.766**
(1 = Yes)	[0.276]	[0.316]	[0.315]	[0.355]	[0.329]
Number of observations	27,533	34,838	36,887	41,911	46,594
Number of individuals	14,302	15,001	13,738	12,046	10,212
Mean dependent var.	1.863	2.051	2.247	3.111	3.830
Individual-fixed effects	YES	YES	YES	YES	YES
Dwelling-fixed effects	YES	YES	YES	YES	YES
Year-fixed effects	YES	YES	YES	YES	YES
Panel B. Days on sick leave					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Days on sick leave	**Days on sick leave**	**Days on sick leave**	**Days on sick leave**	**Days on sick leave**
	Age 18–30	**Age 31–40**	**Age 41–50**	**Age 51–63**	**Age >64**
Needs partial renovation	0.122	0.088	1.344**	−0.812	−0.043
(1 = Yes)	[0.414]	[0.559]	[0.638]	[0.718]	[0.155]
Needs major renovation	−1.007	1.414	1.747	−1.390	−0.235
(1 = Yes)	[1.927]	[1.495]	[1.687]	[1.890]	[0.214]
Number of observations	29,623	36,933	38,280	42,886	47,031
Number of individuals	15,654	16,442	14,627	12,510	10,287
Mean dependent var.	4.849	6.143	7.393	8.515	0.571
Individual-fixed effects	YES	YES	YES	YES	YES
Dwelling-fixed effects	YES	YES	YES	YES	YES
Year-fixed effects	YES	YES	YES	YES	YES

Note. Coefficients for year-fixed effects and sociodemographic controls are not reported due to space limitations (available upon request). Heteroskedasticity-robust standard errors are reported in brackets. Standard errors are clustered at household level.
*$p < .10$; **$p < .05$; ***$p < .01$.

The differences in health status associated with housing conditions seem to be augmented over the lifetime of an individual. Panels A and B of Table 6 provide the results regarding age effects, based on the fixed-effects models. The tables show marginal effects of housing conditions on doctor visits and sick leave for five different age groups: respondents below 30 years old, 31–40, 41–50, 51–63, and those with an age of 64 and older. For the youngest group, we do not find a significant relationship between housing conditions and health, no matter whether we look at doctor visits or sick leave. However, for the 31–40 and 41–50 age groups, we find a marginally statistically significant (at 10%) effect on doctor visits when homes are in need of a major renovation: these respondents visit their doctor, respectively,

exposed to poor housing conditions, the effects of deficient housing are similar for them as compared to higher-income groups. Results available upon request.

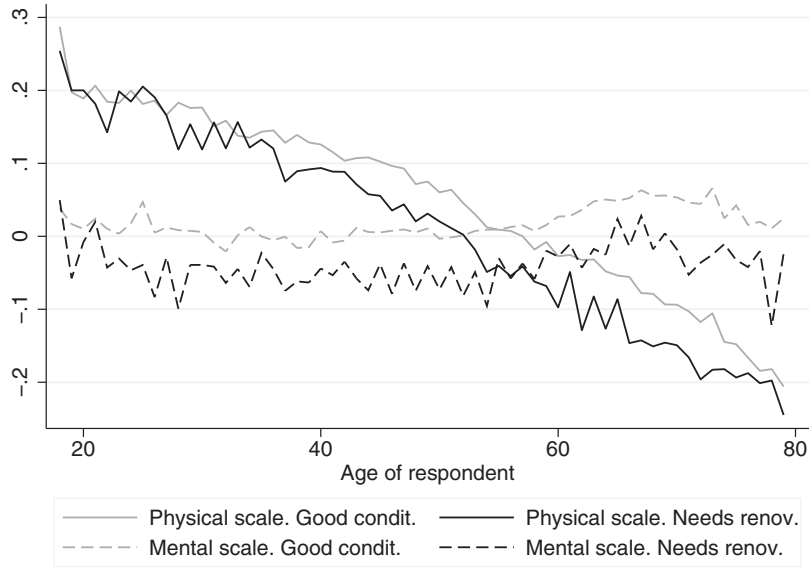


FIGURE 2 Housing conditions and occupant mental and physical health over lifetime

Note. This figure shows the standardized conditional mean of physical and mental scales for the sample of individuals that report living in a house in good conditions and those report living in a house in need of repairs, over the lifetime of an individual. The conditional mean is constructed from the regression controlling for gender, income, education, and marital status. Mental and physical scales range from 0 to 100 (available for survey waves 2002, 2004, 2006, 2008, 2010, 2012, and 2014).

25% more often than people of the same age who reside in a home that is in good condition. The documented effect is strongest for citizens aged 64 and older: if their home needs a partial renovation, they visit the doctor 6% more often, increasing to 20% if the home needs a major renovation. So, our overall results seem to be driven by a particular group of citizens: the elderly.[13]

For sick leave, we generally find no statistically significant results, except for the 41–50 age group. When they inhabit homes in need of a partial renovation, their sick leave is 1.34 days (24.3%) higher than people of the same age group who live in a home that is in a good condition. For those living in homes that are in need of a major renovation, the coefficient increases to 1.75, but is no longer statistically significant.[14] The fact that we do not find any effects in the older age cohorts is most likely due to low labor market participation. In the 51–63 age group, labor market participation in Germany decreases quite rapidly.

Figure 2 shows the conditional average scores in mental and physical health for individuals living in houses in good condition, and those living in houses that need a major renovation. The conditional

[13]To explore age heterogeneity further, we have also looked at health effects for children. The GSOEP recently created a data set monitoring the development of children from birth to the age of 10 (Goebel, 2017). Unfortunately, the sample size is substantially smaller than the original adult sample. In total, the data set contains 12,661 children, but enough information regarding the questions relevant to our study has been provided for only 139 children. When we employ our fixed-effect specification for the children sample, using the weight of the child, parental income, tenancy status, and working status as controls, we find some evidence that housing conditions affect children's health.

[14]It is quite possible that this is due to relatively low statistical power: whereas we have over 15,000 observations in age group 41–50 for dwellings that need a partial renovation, we have just 1,100 observations (approximately 300 participants) in that age group for homes in need of a major renovation.

means are based on the residuals of the regression of mental and physical scales on a set of sociodemographic controls (i.e., income, gender, labor status, education, and household member per room). While the differences between the two groups are relatively small in early adult life, the differences become more pronounced in later years. As the respondents get older, the health gap associated with housing conditions grows.

These findings have some implications for the interpretation of our results, and for the possible mechanism that relates housing conditions to health outcomes. First, the fact that we document effects for doctor visits, but not for sick leave, may be related to the age results reported above. Most of the overall effect seems to be driven by older citizens, who do not tend to work. So, if they fall ill due to poor housing conditions, they may go to the doctor, but they do not take sick leave.

Second, the age effect points to two possible channels between housing conditions and health outcomes. First, it is possible that citizens who are more vulnerable to external health shocks are affected, while people with a robust health are not. In that sense, our results are in line with health effects of major heat waves, cold spells, or salmonella poisoning, which have been shown to affect older citizens disproportionately (Bind et al., 2016). But the age effect may also be determined by differences in exposure. Those individuals of 64 years and older tend not to work and are therefore likely to spend more time at home, thereby increasing their daily exposure to adverse dwelling conditions. Unfortunately, our data set does not allow us to explore this further, given that the information about housing conditions does not provide the specific aspects of what makes housing conditions "poor."[15]

5.4 | Robustness checks

5.4.1 | Health status, home maintenance, and health outcomes

One of the major concerns in estimating the relationship between dwelling conditions and occupant health is that the changes in housing conditions over time are accompanied with other changes in either life conditions or preferences of individuals. For instance, an individual exposed to an unexpected major negative income shock might reduce the investment in housing along with investment in health, for example, by eating cheaper and less healthy food, or by cutting back on the costs associated with physical exercise, like a gym membership. It may also be possible that people who are less interested in health, and thus less willing to make health investments, are also less interested in a healthy living environment, and are thus more likely to occupy a home that is in a poor condition. If this would be the case, the findings reported in Tables 4–6 cannot be interpreted as causal relationships.

In order to test whether housing conditions indeed affect health status and health care utilization, rather than housing conditions and health status both being affected by lifestyle choices, we first estimate the effects of housing conditions on health behavioral measures. We then reestimate the relationship between housing conditions and health outcomes, including smoking as well as the BMI of individuals as health behavior measures. If the inclusion of smoking and the BMI in the regression would reduce or even nullify the previously established effects of poor housing conditions, that would call into question the causal relationship inferred from Tables 4–6. We include a dummy that reflects whether respondents smoke or not, as well as the number of cigarettes for the smokers, and we include the BMI directly into the model.

We report estimation results for the fixed-effects models in Table 7. In columns (1) and (2), we provide the estimation results regarding the impact of housing conditions on occupants' BMI and

[15]Other national household panel surveys, such as those for the United Kingdom and the Netherlands, provide more specific information about exact housing conditions, including dampness, rot, black mold, and noise. Exploring these data sets may provide more insight into the mechanisms between housing conditions and health outcomes.

TABLE 7 Estimation results housing condition and health behavior

	(1) Body mass index	(2) Smoke (1 = Yes)	(3) Log of physical scale	(4) Log of mental scale	(5) Doctor visits	(6) Days on sick leave
Needs partial renovation (1 = Yes)	0.012	−0.001	−0.009***	−0.018***	0.223***	0.355
	[0.027]	[0.005]	[0.003]	[0.003]	[0.063]	[0.359]
Needs major renovation (1 = Yes)	−0.018	−0.004	−0.017**	−0.040***	0.796***	−0.344
	[0.089]	[0.011]	[0.008]	[0.011]	[0.184]	[1.155]
Observations	83,223	70,334	68,141	68,140	69,824	69,825
R^2	.056	.024	.033	.009	.004	.003
Number of individual–dwellings	33,970	30,215	29,688	29,688	30,007	30,008
Mean dependent variable	25.69	0.336	3.883	3.895	2.612	5.490
Individual–dwelling fixed effects	YES	YES	YES	YES	YES	YES
Health behavior controls	NO	NO	YES	YES	YES	YES
Sociodemographic controls	YES	YES	YES	YES	YES	YES
Year-fixed effects	YES	YES	YES	YES	YES	YES

Note. Coefficients for year-fixed effects and sociodemographic controls are not reported due to space limitations (available upon request). Heteroskedasticity-robust standard errors are reported in brackets. Standard errors are clustered at household level. Body Mass Index, mental and physical scales, and smoking variables are available for survey waves 2002, 2004, 2006, 2008, 2010, 2012, and 2014.
*$p < .10$; **$p < .05$; ***$p < .01$.

smoking behavior. The estimation results show that housing conditions have no significant impact on individuals' health behavior outcomes. The BMI and smoking behavior of those individuals living in poorly maintained homes do not differ significantly from those individuals living in homes that are in good condition.

Columns (3), (4), (5), and (6) provide the estimation results of the fixed-effect models for health outcomes, after controlling for individuals' BMI and smoking behavior. When comparing these coefficients with those reported in Tables 4 and 5, it is apparent that the inclusion of the lifestyle variables does not significantly affect the housing condition results. For physical and mental health, the lifestyle variables do not make any difference for the housing condition effect, no matter whether the home is in need of a partial or a full renovation. For doctor visits, the coefficients for housing condition variables change, but they seem to get stronger, rather than weaker. However, this may also be caused by a sampling effect—we can include the lifestyle controls into the regressions on bad health and doctor visits for just a quarter of the observations. For sick leave, we document no statistically significant effect. These results provide some indication that the evidence provided in Tables 4–6 are not likely to be caused by lifestyle choices that affect both housing and health investments.

5.4.2 | Nonparametric event studies

In this subsection, we present the results of an event study based on home renovations of the dwellings of individuals in our sample. This method has been recently used by studies in economics to provide quasi-experimental evaluations of the impact associated with hospital admissions for families (Dobkin, Finkelstein, Kluender, & Notowidigdo, 2018) or the effect of public spending on schools on academic performance (Lafortune, Rothstein, & Schanzenbach, 2018). We use home renovations as an exogenous, major trigger of changes in housing conditions. This strategy helps to separate the impact of home conditions on health outcomes from other potential secular trends, and from the potential endogeneity

of reported housing conditions on health status. In particular, we analyze the coefficients associated with various year indicators describing the changes in health conditions of respondents in the years before and after the renovation event.

The nonparametric event study specification takes the following form:

$$DoctorVisits_{i,d,t} = \sum_{r=-4}^{-2} \mu_r + \sum_{r=0}^{3} \mu_r + \lambda X_{i,t} + \delta Z_{d,t} + \alpha_i + t_t + \epsilon_{i,d,t}, \quad (2)$$

where $DoctorVisits_{i,d,t}$ describes the number of doctor visits of individual i, living in dwelling d in year t; μ_r are the key coefficients; they describe the changes in visits to the doctor ($DoctorVisits_{i,d,t}$) relative to the omitted time category, μ_{-1}, year before the renovation. The rest of variables and fixed-effects in the event study are the same as in our main specification (Equation 1).

We use the nonparametric event study to examine trends in doctor visits around the renovation event. Figure 3 displays the changes in doctor visits before and after the renovation event. For this robustness check, the sample is restricted to tenants. As discussed in the methodology section, for tenants the decision to renovate a home is made by a landlord, and is as such exogenous to the tenant's health.

Panel (a) describes the changes in doctor visits before and after a renovation of the house. Panel (a) includes all types of home renovations, while restricting the sample to renovations paid for by the landlord ($N = 4,238$). We compute the year that the renovation took place in a dwelling based on a dummy variable that takes the value of one when there is any renovation work. In Panel (b), we present the results of renovations of heating systems ($N = 1,289$), and in Panel (c) we display the effect of window renovations ($N = 2,692$).

In all three figures, we observe no indication of pretrends: none of the coefficients of the year indicators preceding the renovations is significantly different from zero. Importantly, we observe a significant drop in doctor visits following home renovations, with the coefficients indicating a decrease in doctor visits of -0.225 (year $t + 1$) to -0.284 (year $t + 3$). This corresponds to a decrease of 8% and 10% in the average number of doctor visits in the estimation sample ($\mu = 2.90$), respectively.

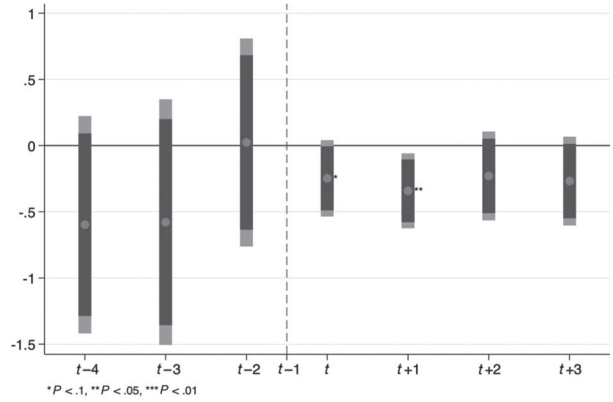
The results presented in this subsection indicate the lack of secular trends leading to the renovation event, and show that exogenous renovation shocks significantly reduce doctor visits in a similar magnitude to the effects described in the main result section of the paper, corroborating the findings on home conditions and health outcomes.

5.5 | Housing conditions and avoidance behavior

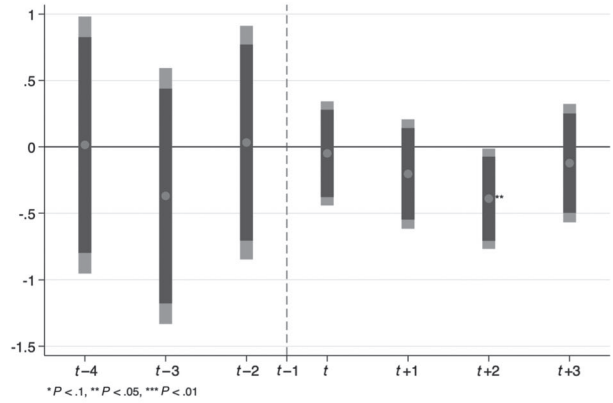
The literature shows that individuals do not necessarily remain passive toward the hazards in their living environments. Agents tend to take multiple actions to avoid or reduce their exposure to health-detrimental environmental conditions. Evidence from the housing market shows that households are willing to pay a premium to live in neighborhoods with cleaner air, or to stay away from sources of air pollution such as toxic plants (see, e.g., Chay & Greenstone, 2005; Currie et al., 2015). In addition, individuals exchange outdoor leisure for indoor leisure in order to reduce their exposure to negative external conditions, spending more time indoors in highly polluted areas or on extremely hot days (Neidell, 2009; Zivin & Neidell, 2014). Similarly, studies on lead paint remediation programs provide evidence of avoidance behavior relative to sources of indoor pollution. Individuals are willing to pay a rent or price premium to be in houses that are certified to be lead-free (Billings & Schnepel, 2017).

We explore different behavioral reactions aimed at avoiding the exposure to (poor) housing conditions. In essence, agents have two main ways to change their exposure to poor housing conditions:

(a) Event study home renovations paid by landlord



(b) Event study heating modernization paid by landlord



(c) Event study window modernization paid by landlord

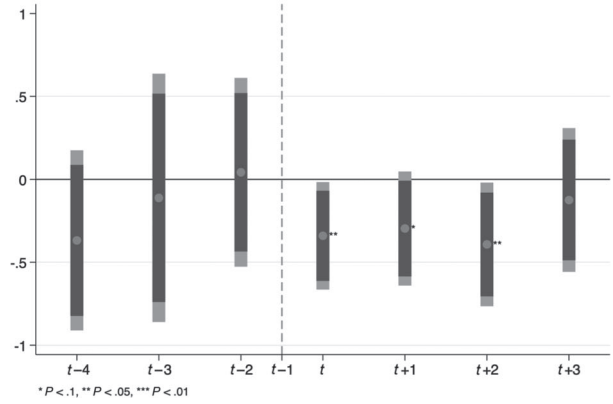


FIGURE 3 Impact of home renovations on number of visits to the doctor

Note. The points represent the estimated effects of time indicators (i.e., the $\mu_r's$ from the nonparametric event study (Equation 2)). The dashed line describes the reference year ($r = -1$), the remainder coefficients represent changes in doctor visits with respect to μ_{-1}. The black (gray) bars show the 90% (95%) confidence intervals. The empirical model includes a full set of controls and fixed effects, as described in Equation 1. The standard errors are clustered at the household level. The sample is restricted to tenants in all regressions.

TABLE 8 Housing conditions and avoidance behavior

Panel A. Avoidance behavior to deficient housing condition					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Move$_t$ (1 = Yes)		**Renovation in dwelling$_t$ (1 = Yes)**		
	Tenant	**Homeowner**	**Tenant (Self-paid)**	**Tenant (Paid by landlord)**	**Homeowner**
Needs partial renovation$_{t-1}$	0.010***	0.012***	0.008***	0.030***	0.074***
	[0.002]	[0.002]	[0.002]	[0.003]	[0.007]
Needs major renovation$_{t-1}$	0.034***	0.029***	0.005	0.047***	0.226***
	[0.005]	[0.009]	[0.005]	[0.008]	[0.026]
Observations	118,298	133,248	109,712	109,712	123,906
R^2	.033	.013	.004	.005	.010
Number of individuals	21,251	21,604	18,589	18,589	18,758
Mean dependent var.	0.0232	0.0232	0.039	0.144	0.199
Sociodemographic controls	YES	YES	YES	YES	YES
Year-fixed effects	YES	YES	YES	YES	YES
Individual-fixed effects	YES	YES	YES	YES	YES
Dwelling-fixed effects	NO	NO	YES	YES	YES

Panel B. Years in need of renovation by ownership status	
	(1)
	Years in need of renovation
Tenant (1 = Yes)	1.312***
	[0.105]
Observations	300,065
Sociodemographic controls	YES
Dwelling controls	YES
Year-fixed effects	YES

Note. Coefficients for year-fixed effects and sociodemographic controls not reported due to space limitations (available upon request). Heteroskedasticity-robust standard errors are reported in brackets. Standard errors are clustered at household level. The list of dwelling controls includes the size, number of rooms, and year of construction in the apartment. The list of individual socioeconomic controls includes the monthly income, education years, whether the individual has a college degree, gender, and age.

*$p < .10$; **$p < .05$; ***$p < .01$.

either through moving or through renovation. In this part of the paper, we explore how poor housing conditions affect the likelihood of either of these two actions, distinguishing between homeowners and tenants.

Table 8, Panel A presents the estimation results. Columns (1) and (2) provide the estimates of the link between poor housing conditions and the probability of moving, with column (1) documenting the results for tenants and column (2) documenting the results for homeowners. The estimates indicate that individuals in our sample indeed seem to avoid poor housing conditions by moving to a different address. Both tenants and homeowners are more likely to move in the year after reporting that their home is in need of partial or major renovation, with the likelihood of moving increasing with more detrimental housing conditions. Interestingly, the effects are almost comparable for tenants and homeowners—both groups are about 1% more likely to move if their home needs partial renovation and are 3% more likely to move if it needs a major renovation. This result suggests that tenants and homeowners equally dislike living in a poorly maintained home, and "vote with their feet" in a similar manner.

The other possible response to adverse housing conditions is renovating the home. Here, we find very different results. For both tenants and homeowners, we observe an increased likelihood of renovation following poor housing conditions, but the extent of the effect differs substantially across the two groups. Columns (3) and (4) show estimation results for tenants, distinguishing between renovations paid by the tenant and paid by the landlord. The estimation results in column (3) indicate that tenants tend not to renovate their dwelling after they start reporting problems with the housing conditions. Landlords, however, show a higher propensity to renovate the dwellings they own when their tenants report problems with the housing conditions: the likelihood of a renovation is 3% higher when a partial renovation is needed, and 4.7% higher when a major renovation is required. But this effect is trumped by the effects observed for homeowners, who are 7.4 more likely to renovate their home after reporting the need for a partial renovation, and are 22.6% more likely to renovate in case of the need for a major renovation.

These results point at a split incentive or external effects problem, where the agent making the investment decision is not the direct beneficiary of the investment outcomes. Homeowners reap the full benefit of their renovation investments, both in increased house value (see, for instance, Billings & Schnepel, 2017) and in improved health and comfort. Landlords, on the other hand, only receive the benefit of increased home values following renovations, while the health benefits affect the tenants only. And if tenants would pay for the renovation, they would receive the health and comfort benefits, while their landlord would receive the increase in home value.

Standard economic theory predicts underinvestment in the latter two cases, which is aligned with the results presented in Table 8, Panel A. Although tenants and homeowners similarly dislike living in poor housing conditions, as suggested by their comparable likelihood to move, tenants are much more likely to face prolonged exposure to such conditions. In Table 8, Panel B, we provide evidence of this, showing that tenants spend 1.3 years longer in a house that needs a renovation than homeowners, thereby suffering longer from adverse indoor environmental conditions.

6 | CONCLUSION

The predicted rise in health care spending is a major concern for developed economies. Environmental conditions have been shown to significantly affect public health outcomes, and over the past decades, public policy has addressed issues ranging from curbing CO2 emissions to reducing the detrimental effects of heat waves (see Deschenes, 2014; Zivin & Neidell, 2013). However, it is estimated that in developed economies, individuals spend more than 90% of their time indoors. Understanding the effect of indoor conditions on health outcomes is thus critical, for policymakers, private market participants, and academia alike.

This study explores whether and how the condition of homes affect the health of their inhabitants. The limited number of existing studies on the topic of housing conditions and health outcomes either fail to establish causality, or address housing conditions in poor areas, often in slums or developing countries, making the results hard to generalize to developed economies.

Using a long-running household panel data set, the GSOEP, this paper attempts to identify a causal link between housing conditions and health outcomes. The sample includes more than 300,000 respondent/year observations for the period between 1992 and 2014, allowing for monitoring of the health outcomes of the same individual, exposed to varying housing conditions, over the sample period. Our empirical specification exploits the changes in health outcomes associated with within-individual variation in housing conditions, and focuses specifically on tenants, for whom home renovation is exogenous to health outcomes.

The results provide evidence that residents of poorly maintained dwellings report a lower subjective health status and visit the doctor 11% more often. An event study around home renovation corroborates these findings. Regarding doctor visits, we do not find a significant effect on the likelihood of visiting the doctor in the first place (the intensive margin), but once individuals go to the doctor, they go significantly more often when they live in a dwelling in need of renovation (the extensive margin). Regarding sick leave, we find some evidence on the salience of housing conditions, but not in the most extensive model.

These effects are stronger for dwellings that are in need of a major renovation rather than a partial renovation. The results hold across income groups, and for both owner-occupiers and tenants. Given that results remain robust after controlling for lifestyle indicators such as BMI and smoking, we conclude that the documented effects are not caused by common underlying lifestyle choices, but that the causality runs from housing conditions to health outcomes.

We also investigate heterogeneity by age cohorts. For the age cohort under 31 years, we find no significant relationship between housing conditions and health, while that relationship materializes for the older age cohorts, and is especially strong for those aged 64 and over. For the latter, we document 6% more visits to the doctor when a home is in need of a partial renovation, increasing to 20% when the home is in need of a major renovation. This may explain the absence of effects for sick leave as compared to doctor visits: those individuals with an age of 64 and older tend not to work, so do not report sick for work, even if they are ill and have to go to the doctor.

Finally, we analyze avoidance behavior, by investigating the likelihood of moving and renovation when respondents report poor housing conditions. We find that tenants and homeowners are equally likely to move in the year after reporting poor housing conditions, suggesting that they equally dislike poor housing conditions. However, we also document that homeowners are almost 23% more likely to renovate their home under these circumstances, while that percentage is much lower for tenants, no matter whether they or their landlord pay for the renovation. This finding suggests underinvestment in home renovation in the rental market, resulting in prolonged exposure to an adverse indoor environment, likely leading to reduced health outcomes.

The results of this paper indicate that the condition of individuals' homes affects their health in a statistically and economically significant manner, especially when these individuals get older. Apart from direct, but hard-to-measure, individual welfare effects, the economic costs for society mainly materialize in higher consumption of health services rather than sick leave. Even though the medical care system in Germany is socialized, and the housing market lacks transparency (Germany does not maintain publicly available property records), we can do a simple back-of-the-envelope welfare analysis.

The GSOEP survey is representative for Germany, and we thus infer that 29% of German homes need some form of renovation. Based on the findings in this paper, improving the maintenance status for homes that need renovation would reduce visits to the doctor by 11%. In Germany, the cost of doctor visits is difficult to calculate, given the fact that healthcare is socialized, we therefore make inferences based on total health care spending, assuming that doctor visits lead to follow-up procedures, and the increase in doctor visits is thus a good indication for a possible increase in overall health care spending.

The 2017 health care spending in Germany was EUR 374.2 billion—assuming that health care spending is equally distributed across households and homes (arguable, this is a heroic assumption), reducing health care spending for 29% of households by 11% would lead to annual savings on health care costs of EUR 11.9 billion. Assuming perpetuity, no growth in health care costs, and a cost of capital of 2%, the annual health care savings would translate into a present value of EUR 594 billion.

To achieve these savings, German landlords would have to invest significantly into their investment properties, and homeowners would have to improve the quality of their homes. The current housing

stock in Germany consists of some 41 million homes and apartment units, of which about 50% are apartments (20.8 million units in 3.1 million apartment buildings). Data on the cost of renovations are not available systematically, but assuming an investment of EUR 50,000 to significantly improve the maintenance status of a home (25% of the cost of an average home) and an investment of EUR 25,000 to improve the quality of an apartment unit (there are economies of scale to be achieved in apartment buildings, given the extent of shared walls and shared services), the aggregate cost of upgrading the 29% of the building stock with deficiencies in maintenance would be EUR 444 billion.

This simple calculation suggests that the net present value of future savings on health care costs far outweighs the costs of upgrading the building stock. This example ignores cobenefits from improving the building stock, such as reduced energy consumption, increased comfort, and the subsequent private benefits of increasing house prices, which would accrue to landlords and homeowners.

These findings imply that investments in home improvement can have important positive external effects, which are currently not taken into account when evaluating such investments. As our societies grow older, these external effects will only increase, making the relevance of the building stock for health outcomes ever more important. Public policy measures aimed at maintaining and improving the condition of the building stock could have tangible effects on prevention of disease, thereby reducing the burden on the health care system and its finances.

ACKNOWLEDGMENTS

We thank an anonymous referee, Wenlan Qian, the editor, Luke Munford, Danny Ben-Shahar, participants at the 2018 AEA meetings, the 2016 International AREUEA conference, the Green and Healthy Homes Conference in Maastricht, and the 4th European Health Economics Association Conference for their helpful comments. We also thank DWI Berlin for providing access to the GSOEP survey data. Aydin, Kok, and Palacios are financed by a VIDI grant from the Dutch national science organization (NWO).

ORCID

Nils Kok https://orcid.org/0000-0003-0764-9649

REFERENCES

Adams, P., Hurd, M., McFadden, D., Merrill, A., & Ribeiro, T. (2003). Healthy, wealthy, and wise? Tests for direct causal paths between health and socioeconomic status. *Journal of Econometrics*, *112*(1), 3–56.

Andersen, H., Mühlbacher, A., Nübling, M., Schupp, J., & Wagner, G. (2007). Computation of standard values for physical and mental health scale scores using the SOEP version of SF12v2. *Journal of Applied Social Science Studies (Schmollers Jahrbuch)*, *127*(1), 171–182.

Barreca, A. I. (2012). Climate change, humidity, and mortality in the United States. *Journal of Environmental Economics and Management*, *63*(1), 19–34.

Barron, M., & Torero, M. (2017). Household electrification and indoor air pollution. *Journal of Environmental Economics and Management*, *86*, 81–92.

Bilger, M., & Carrieri, V. (2013). Health in the cities: When the neighborhood matters more than income. *Journal of Health Economics*, *32*(1), 1–11.

Billings, S. B., & Schnepel, K. T. (2017). The value of a healthy home: Lead paint remediation and housing values. *Journal of Public Economics*, *153*, 69–81.

Bind, M., Peters, A., Koutrakis, P., Coull, B., Vokonas, P., & Schwartz, J. (2016). Quantile regression analysis of the distributional effects of air pollution on blood pressure, heart rate variability, blood lipids, and biomarkers of inflammation in elderly American men: The normative aging study. *Environmental Health Perspectives*, *124*(8), 1189–1198.

Cattaneo, M. D., Galiani, S., Gertler, P. J., & Martinez, S. (2009). Housing, health, and happiness. *American Economic Journal: Economic Policy*, *1*(1), 75–105.

Chay, K. Y., & Greenstone, M. (2005). Does air quality matter? Evidence from the housing market. *Journal of Political Economy*, *113*(2), 376–424.

Contoyannis, P., Jones, A. M., & Rice, N. (2004). The dynamics of health in the British Household Panel Survey. *Journal of Applied Econometrics*, *19*(4), 473–503.

Currie, J. (2009). Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature*, *47*(1), 87–122.

Currie, J., Davis, L., Greenstone, M., & Walker, R. (2015). Environmental health risks and housing values: Evidence from 1,600 toxic plant openings and closings. *American Economic Review*, *105*(2), 678–709.

Currie, J., Hanushek, E. A., Kahn, E. M., Neidell, M., & Rivkin, S. G. (2009). Does pollution increase school absences? *Review of Economics and Statistics*, *91*(4), 682–694.

Currie, J., & Neidell, M. (2005). Air pollution and infant health: What can we learn from California's recent experience? *Quarterly Journal of Economics*, *120*(3), 1003–1030.

Cutler, D., & Glaeser, E. (2005). What explains differences in smoking, drinking, and other behaviors? *American Economic Review*, *95*(2), 238–242.

Deschenes, O. (2014). Temperature, human health, and adaptation: A review of the empirical literature. *Energy Economics*, *46*, 606–619.

Deschênes, O., & Greenstone, M. (2011). Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US. *American Economic Journal: Applied Economics*, *3*(4), 152–185.

Dieleman, J., Campbell, M., Chapin, A., Eldrenkamp, E., Fan, V., Haakenstad, A., … Reynolds, A. (2017). Future and potential spending on health 2015-40, Development assistance for health, and government, prepaid private, and out-of-pocket health spending in 184 countries. *Lancet*, *389*(10083), 2005–2030.

Dobkin, B. C., Finkelstein, A., Kluender, R., & Notowidigdo, M. J. (2018). The economic consequences of hospital admissions. *American Economic Review*, *108*(2), 308–352.

Ebenstein, A., Fan, M., Greenstone, M., He, G., & Zhou, M. (2017). New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai. *Proceedings of the National Academy of Sciences*, *114*(39), 10384–10389.

Eibich, P. (2015). Understanding the effect of retirement on health: Mechanisms and heterogeneity. *Journal of Health Economics*, *43*, 1–12.

Frijters, P., Haisken-DeNew, J. P., & Shields, M. A. (2005). The causal effect of income on health: Evidence from German reunification. *Journal of Health Economics*, *24*(5), 997–1017.

Galiani, S., Gertler, P. J., Undurraga, R., Cooper, R., Martínez, S., & Ross, A. (2017). Shelter from the storm: Upgrading housing infrastructure in Latin American slums. *Journal of Urban Economics*, *98*, 187–213.

Goebel, J. (2017). *SOEP Core v32*. Documentation on biography and life history data. SOEP Survey Papers, 418.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, *80*(2), 223–255.

Hanna, R., Duflo, E., & Greenstone, M. (2016). Up in smoke: The influence of household behavior on the long-run impact of improved cooking stoves. *American Economic Journal: Economic Policy*, *8*(1), 80–114.

Hanna, R., & Oliva, P. (2015). The effect of pollution on labor supply: Evidence from a natural experiment in Mexico City. *Journal of Public Economics*, *122*, 68–79.

Imelda. (2018). Indoor air pollution and infant mortality: A new approach. *American Economic Association Papers and Proceedings*, *108*, 416–421.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., … Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, *11*(3), 231–252.

Kuenn, S., & Palacios, J. (2017). The impact of housing quality on health and labor market outcomes. http://conference.iza.org/conference_files/SUM_2019/palacios_j24419.pdf

Künn-Nelen, A. (2016). Does commuting affect health? *Health Economics*, *25*(8), 984–1004.

Lafortune, J., Rothstein, J., & Schanzenbach, D. W. (2018). *School finance reform and the distribution of student achievement*. *10*(w22011), 1–26.

Ludwig, J., Duncan, G. J., Gennetian, L. A., Katz, L. F., Kessler, R. C., Kling, J. R., … Sanbonmatsu, L. (2012). Neighborhood effects on the long-term well-being of low income adults. *Science*, *337*, 1505–1510.

Luechinger, S. (2009). Valuing air quality using the life satisfaction approach. *Economic Journal*, *119*(536), 482–515.

Marcus, J. (2013). The effect of unemployment on the mental health of spouses—Evidence from plant closures in Germany. *Journal of Health Economics*, *32*(3), 546–558.

Neidell, M. (2009). Information, avoidance behavior, and health. The effect of ozone on asthma hospitalizations. *Journal of Human Resources*, *44*(3), 450–478.

Pohlmeier, W., & Ulrich, V. (1995). An econometric model of the two-part decisionmaking process in the demand for health care. *The Journal of Human Resources*, *30*(2), 339–361.

Pollack, C. E., von dem Knesebeck, O., & Siegrist, J. (2004). Housing and health in Germany. *Journal of Epidemiology and Community Health*, *58*(3), 216–222.

Reinhold, S., & Jürges, H. (2010). Secondary school fees and the causal effect of schooling on health behavior. *Health Economics*, *19*(8), 994–1001.

Rosen, G. (2015). *A history of public health*. Baltimore: JHU Press.

Santos Silva, J. M., & Windmeijer, F. (2001). Two-part multiple spell models for health care demand. *Journal of Econometrics*, *104*(1), 67–89.

Schiele, V., & Schmitz, H. (2016). Quantile treatment effects of job loss on health. *Journal of Health Economics*, *49*, 59–69.

Schlenker, W., & Walker, W. R. (2016). Airports, air pollution, and contemporaneous health. *Review of Economic Studies*, *83*(2), 768–809.

Shaw, M. (2004). Housing and public health. *Annual Review of Public Health*, *25*, 397–418.

Smith-Sivertsen, T., Díaz, E., Pope, D., Lie, R. T., Díaz, A., McCracken, J., … Bruce, N. (2009). Effect of reducing indoor air pollution on women's respiratory symptoms and lung function: The RESPIRE Randomized Trial, Guatemala. *American Journal of Epidemiology*, *170*(2), 211–220.

Thomson, H., Thomas, S., Sellstrom, E., & Petticrew, M. (2009). The health impacts of housing improvement: A systematic review of intervention studies from 1887 to 2007. *American Journal of Public Health*, *99*(3), S681–S692.

Wagner, G., Frick, J., & Schupp, J. (2007). The German socio-economic panel study (SOEP)—scope, evolution and enhancements. *Journal of Applied Social Science Studies*, *127*(1), 139–169.

WHO. (2007). *Large analysis and review of European housing and health Status (LARES)*. Technical report.

Winkelmann, R. (2004). Health care reform and the number of doctor visits - An econometric analysis. *Journal of Applied Econometrics*, *19*(4), 455–472.

Zivin, J. G., & Neidell, M. (2013). Environment, health, and human capital. *Journal of Economic Literature*, *51*(2012), 689–730.

Zivin, J. G., & Neidell, M. (2014). Temperature and the allocation of time: Implications for climate change. *Journal of Labor Economics*, *32*(1), 1–26.

How to cite this article: Palacios J, Eichholtz P, Kok N, Aydin E. The impact of housing conditions on health outcomes. *Real Estate Econ*. 2020;1–29. https://doi.org/10.1111/1540-6229.12317

APPENDIX

TABLE A1 Home maintenance and health in rental sample

	(1) Renov. paid by landlord$_t$	(2) Renov. paid by landlord$_t$	(3) Renov. paid by landlord$_t$	(4) Renov. paid by landlord$_t$	(5) Renov. paid by landlord$_t$	(6) Renov. paid by landlord$_t$	(7) Renov. paid by landlord$_t$	(8) Renov. paid by landlord$_t$
Tenants bad health status (1 = Yes)$_{t-1}$	−0.004	−0.004						
	[0.003]	[0.003]						
Log tenant mental scale$_{t-1}$			−0.015	−0.015				
			[0.010]	[0.010]				
Log tenant physical scale$_{t-1}$					0.001	0.002		
					[0.013]	[0.013]		
Tenant doctor visits$_{t-1}$							0.000	0.000
							[0.000]	[0.000]
Number of observations	106,885	106,499	29,374	29,293	29,375	29,294	98,185	97,854
Number of individuals	17,798	17,784	10,965	10,951	10,965	10,951	17,526	17,511
House conditions	NO	YES	NO	YES	NO	YES	NO	YES
Year-fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Individual-fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Socioeconomic controls	YES	YES	YES	YES	YES	YES	YES	YES
Only tenants	YES	YES	YES	YES	YES	YES	YES	YES

Note. Coefficients of year-fixed effects and sociodemographic controls are not reported due to space limitations (available upon request). Heteroskedasticity-robust standard errors are reported in brackets. Standard errors are clustered at household level. Body mass index, mental and physical scales, and smoking variables are available for survey waves 2002, 2004, 2006, 2008, 2010, 2012, and 2014.
$^{*}p < .10$; $^{**}p < .05$; $^{***}p < .01$.