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HOUSING AND HEALTH

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Deprived housing is recognized as a source of poor health, but there is still little evidence of a causal relationship between housing and health. While existing literature identifies neighborhood effects and the individual dwelling as factors which affect health, it does not offer a joint examination of these factors. Moreover, endogeneity is a concern in analyses of both problems. Thus far, studies addressing endogeneity have done so through experimental design or instrumental variables. The first approach suffers from problems of external validity and the latter from the lack of reliable instruments. We therefore adopt an alternative strategy which considers both sources of endogeneity in order to identify the effects of housing on health by estimating fixed-effect models. We reveal how housing problems affect health depending on living conditions and socioeconomic status. Our results therefore indicate that living in poor housing is an important short-term socioeconomic determinant that directly affects health.

JEL Codes: I14, I18, R20

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1. Introduction

Housing is an important aspect of an individual's standard of living, and poor housing conditions present a considerable challenge to social inclusion. Housing costs also represent a significant share of total household expenditures. In 2007, approximately 12.5 percent of the EU27 population lived in households that spent 40 percent or more of their equivalized disposable income on housing (Eurostat, 2010). To address these challenges, modern welfare states have developed a multitude of policies to mitigate the financial burden and the threat of social exclusion posed by poor housing conditions. As well as limiting the cost of living, these expenditures are also justified by their positive spillover effects on a variety of desired socioeconomic outcomes.

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Indeed, many cross-sectional studies document the spillover effects of housing assistance programs on desirable outcomes such as improved health, fewer behavioral problems, greater educational attainment, and increased labor force participation. However, evidence for a causal link between poor housing conditions and socioeconomic outcomes remains sparse (Newman, 2008). The main problem is that it is difficult for empirical research using observational data to accurately identify the effect of poor housing conditions on the respective outcome. Individuals choose neighborhoods and dwellings for reasons that are difficult to measure. Consequently, empirical analyses suffer from selection bias if they fail to consider individual characteristics that influence the outcome variable and the sorting process into neighborhoods and dwellings (Ludwig *et al*., 2008). Many authors devote substantial effort to identifying separate effects that may jointly influence health and neighborhood choice (e.g. Katz *et al*., 2001; Ludwig *et al*., 2001; Kling *et al*., 2007; Bilger and Carrieri, 2013), yet neglect them when considering the choice of individual dwellings. Failing to control for all sources of endogeneity may result in inconsistency of all parameters in the estimated equations.

The aim of this paper is therefore to account for both dimensions of deprived housing—that is, poor neighborhoods and poor dwellings—and to identify direct effects of bad housing on health. We analyze four waves of EU-SILC (European Union Survey on Income and Living Conditions, Eurostat User Database) panel data (2005–8) for 21 European countries. EU-SILC data provide a massive sample and thus greater test power compared to existing studies. The data allow us to use time and person fixed effects to control for unobserved heterogeneity in the selection of dwellings and neighborhoods. The use of panel data also makes it possible to address problems of potential simultaneity between health and socioeconomic control variables, such as income, wealth, or education. Finally, having large-scale panel data facilitates the identification of effects over a short time period, which are expected to be potentially small in substantive terms. We can thus reveal how housing problems affect health differently, depending on living conditions and socioeconomic status. In summary, the overall aims of our research are to improve the empirical estimation strategy which is applied to observational data in order to reveal causal pathways between housing deprivation and health, and to offer insights on the heterogeneous effects of deprived housing conditions on health.

2. Housing, Neighborhoods, and Health

The existing literature on the relationship between poor housing and health can be classified into two strands: one concerned with the influence of neighborhood effects on health and a second exploring how poor dwelling conditions and insufficient basic facilities affect health. Unfortunately, there is little overlap, little cross-referencing, and there are few integrated analyses of the two issues. In this section, we will review both strands.[1]

[1]We concentrate on studies applying methods that are able to establish a causal link between bad housing and health. We also concentrate on papers from developed countries, leaving aside the issue of the lack of basic facilities in developing countries.

2.1. *Neighborhood Effects*

Selection bias and endogeneity problems are a major concern in empirical research on neighborhood effects and health. Studies attempting to establish a causal link between measures of poor housing and health thus either conduct (quasi-)experiments or apply instrumental variables methods to observational data in order to circumvent problems of unobserved heterogeneity. Examples of the former approach are papers on the Moving to Opportunity (MTO) program in the United States (U.S.), a randomized relocation of deprived families from high-poverty areas to low-poverty areas. These studies do not find significant overall effects of relocation on adults' physical health, but report that movers experience a substantial reduction in mental health problems (Katz *et al*., 2001; Ludwig *et al*., 2001; Kling *et al*., 2007). These mental health improvements are traced back to a fall in stress levels due to moving "away from dangerous neighborhoods in which the fear of random violence influenced all aspects of their lives" (Kling *et al*., 2007, p. 102). While the MTO program provides compelling evidence of a causal link between bad housing and particular health indicators, there is still the problem of a tradeoff between the neat identification of an intervention and maintaining the external validity of the research design. For instance, Ludwig *et al*. (2008) admit that the MTO results only reflect the specific situation of individuals eligible for high-rise public housing in the five cities participating in the MTO program at the time of the intervention.

A second approach is an instrumental variables (IV) approach solution (Bilger and Carrieri, 2013). Using Italian cross-sectional data, the authors attempt to solve the selection problem by instrumenting neighborhood conditions with the degree of urbanization to derive the causal effects of neighborhood on health. The study finds that low-quality neighborhoods are strongly health-damaging, with an effect size comparable to the primary/upper secondary education health differential. This negative effect is even higher than the impact of poor economic circumstances on health. As good instruments are notoriously difficult to find, we discuss the validity of the instruments used in this study in Section 3.2.

2.2. *Effects of the Dwelling Unit*

Although the quasi-experimental and IV approaches take the endogeneity of neighborhood selection into account, they do not consider the possibility of an endogenous relationship between health and poor dwelling unit conditions.[2] However, there are strong arguments for the link between poor dwellings and health also being susceptible to an endogeneity problem due to sorting.

It is likely that the selection of dwellings is influenced by the same unobservable factors as the selection of neighborhoods and that these factors are correlated with health. For instance, an individual's ability, competence, or initiative (Ludwig *et al*., 2008) might play the same role in finding an adequate neighborhood as in finding an appropriate dwelling. Furthermore, these unobserved factors might not only play a role in finding a dwelling but also in maintaining a

[2]Bilger and Carrieri (2013) control for dwelling conditions but do not account for endogeneity. The MTO papers do not control for dwelling quality.

healthy living environment. The home's physical adequacy—that is, the extent to which the housing stock meets the standard of "a decent home and a suitable living environment"[3]—is a case in point. The physical adequacy of public housing is often ensured by the responsible authorities, whereas many people who do not receive housing assistance would in fact be eligible for it on the basis of currently living in inadequate conditions. In the U.S., for example, the number of households that effectively receive housing assistance is only a third of those that need it (Newman, 2008). However, as housing is not an entitlement but a means-tested benefit in many countries, many people are reluctant to request it, and thus remain living in substandard housing (Smith, 1990). A reason why the MTO papers did not observe any effects of poor housing on physical health could be that they only include people living in public housing.

As ethnic, racial, or socioeconomic segregation is less problematic in Europe than in the U.S. (Musterd, 2005), the problem of endogenous dwelling selection might be even more serious than that of neighborhood selection. This difference can be explained, *inter alia*, by the fact that social-democratic and continental European welfare states differ in their degree of urban planning and the (de)commodification of housing from liberal welfare states such as the U.S. Although the housing sector is heterogeneous across European states (van Kempen and Murie, 2009), extreme segregation as observed in Kling *et al*. (2007) is rare.

The relationship between health and the individual dwelling units physical problems has been studied using observational data by Pevalin *et al*. (2008) in the United Kingdom and Navarro *et al*. (2010) in Spain. Pevalin *et al*. (2008) use seven waves (1996–2002) of the British Household Panel Survey (BHPS), with first differencing to control for time-invariant unobserved heterogeneity. Health outcomes are mental well-being, measured by a 12-item General Health Questionnaire (GHQ), and the number of health problems from which a person suffers. Their results show that an increase in housing problems worsens mental well-being for men and increases the number of general health problems for both men and women. Changes in housing space are not related to either mental well-being or the number of health problems. A heterogeneity analysis showed that increasing housing problems are especially problematic for older men, whereas for women there are no age-specific effects. The Navarro *et al*. (2010) study uses four waves (1995–8) of ECHP data for Spain and estimates a logistic model with individual fixed effects to examine the relationship between physical dwelling problems (measured by a housing deprivation index) and health. They find that overcrowding (the odds ratio, OR = 1.02), lacking central heating (OR = 1.17), as well as structural problems (e.g. a leaky roof, OR = 1.17; too dark, OR = 1.11) increase the probability of self-reported bad health. By constructing a latent variable of housing conditions (including hot running water, central heating, a leaky roof, damp, rot in floors or in window frames, and overcrowding), they demonstrate that moving up to the next score on the housing deprivation scale raises the likelihood of bad health by 80 percent. Neither study takes the simultaneous endogeneity of sorting into housing and neighborhood into account.

[3]https://www.census.gov/content/dam/Census/programs-surveys/ahs/publications/HousingAdequacy.pdf

Transmission Pathways

Most often, inappropriate housing conditions (e.g. overcrowding, poor physical conditions such as damp and mold, or insufficient heating) are associated with respiratory diseases, such as asthma, wheezes and coughs, bronchospasms, rhinitis, and alveolitis. This connection probably results from poor air movement (ventilation) and damp homes, often a consequence of condensation resulting from inadequate ventilation. This contributes to detrimental hygrothermal housing conditions that facilitate the spread of mold, fungi, and other potentially harmful microorganisms (Shaw, 2004). Interior moisture can also be increased by overcrowding, with the consequences described above (Krieger and Higgins, 2002).

The literature points to a number of additional health issues associated with housing problems. Overcrowding is related to an increased transmission probability of various infectious diseases, reduced stature, emotional problems, and social tensions (Krieger and Higgins, 2002; BMA, 2003). Furthermore, deprived physical housing conditions are also linked to recurrent headaches, fever, nausea and vomiting, sore throats, and poor mental health (Krieger and Higgins, 2002). Cold- and heat-related issues in particular are linked to a low general health status, an increased use of health services, poor mental health (Krieger and Higgins, 2002), hypothermia, ischemic heart disease, and myocardial infarction and strokes (BMA, 2003). Taken together, these studies demonstrate which health consequences emerge from deprived housing conditions. In our analysis, we have tried to capture these effects using various health indicators available in our data source (see Section 3.1).

3. Methods

3.1. *Data*

We use four waves of EU-SILC, covering the years from 2005 to 2008. This panel data set provides many socioeconomic variables that confound the effect of housing deprivation on health and thus simplify the identification strategy. The common guidelines and standards for data production also make it possible to compare different European countries.[4]

To capture individual health, we use first *self-assessed health* (SAH), measured as a binary variable, using a value of one if an individual reported (subjective) bad or very bad health and zero otherwise (fair/good/very good health). We employ *limitations to activities of daily living resulting from health problems* (ADL) as the second specification for individual health. This variable takes on three values—strongly limited, limited, and not limited—and is converted into a dummy variable with a value of one if a person reported any limitations and zero otherwise. Finally, we use an indicator reporting *chronic illness*, assigned one if a person mentions a chronic illness and zero otherwise.

[4]Our analysis includes Belgium, Spain, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, the United Kingdom, Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia and Norway.

The main independent variable of interest, *deprived housing conditions*, is operationalized using several items. To capture overcrowding, we include the number of rooms available to a household divided by the equivalized household size.[5] Compared to a simple rooms-per-person ratio, the equivalized household size has the advantage of accounting for the household's configuration. To measure the physical structure of a building, we add a dummy variable with the value of one if the household members live in a building with a leaking roof, damp walls/floors/foundation, or rot in the window frames or floor. Problems with heating conditions are captured through a dummy variable asking whether the household was able to keep the home adequately warm (1 = no, 0 = yes). We refer to the first dummy as *dwelling problems* and to the second as *heating problems*. Finally, we also employ variables that approximate the *hygienic conditions* of the respondents. To do this, we include dummies indicating whether the household has a bath or shower in the dwelling (1 = no, 0 = yes) and an indoor flush toilet for the sole use of the household (1 = no, 0 = yes). *Tenure status* is used as an additional control variable, as it could be correlated with the willingness and/or ability to improve physical housing conditions.

To reduce time-variant unobserved heterogeneity, we control for socioeconomic variables that are typically found to influence health.[6] For our main model, we include *total disposable income*, equivalized by household size and composition and adjusted for purchasing power parity. We also examine several demographic variables. To capture *personal education*, we include the highest International Standard Classification of Education (ISCED) level attained, measured on a six-item scale. We control for *marital status*, measured on a five-item scale (never married, married, separated, widowed, and divorced). We include self-defined *current economic status* measured on a nine-item scale (working full time, working part time, unemployed, pupil/student/further training, unpaid work, retirement or has given up business, permanently disabled or/and unfit to work, in compulsory military community or service, fulfilling domestic tasks and care responsibilities, and other inactive person). Economic status is informative about the effect of housing conditions on health, as it approximately reveals the amount of time a person is exposed to poor housing conditions. Therefore, one would expect that retired persons or persons fulfilling domestic tasks would be more prone to report bad health due to deficient housing than employed persons who spend more time outside the dwelling.

3.2. *Identification Strategy*

The merit of observational data in comparison to (field) experiments is a gain in external validity, albeit at the risk of losing internal validity. In the context of our research design, this especially pertains to the problem of unobserved sorting into neighborhoods and dwellings, simultaneity, and attrition.

[5]The equivalized household size was computed as follows: $1 + 0.5 * HM_{14+} + 0.3 * HM_{13-}$, where HM_{14+} are household members aged 14 and older and HM_{13-} are household members aged 13 or younger.

[6]A descriptive overview of all variables used in the analyses, pooled over time and countries, can be found in Appendix A (in the Online Supporting Information).

Unobserved Sorting into Neighborhoods

Sorting into neighborhoods can lead to endogeneity in the estimation of the effects of bad housing on health. As EU-SILC only provides variables for neighborhood effects in the cross-sectional dimension, we control for neighborhood problems by reducing our data to a non-mover panel. We thereby ensure that variation in health status is not caused by changes in the neighborhood. To obtain a valid causal inference, we assume that: (1) movers represent only a small fraction of the total sample; (2) movers do not differ from non-movers with respect to health; and (3) that over the four-year observation period, the characteristics of the neighborhood remain constant. Regarding the first point, the unconditional moving probability across countries and time (pooled) in our data set, using sampling weights, is 3.7 percent. This demonstrates that residential mobility is much lower in Europe than in the U.S. (about 12 percent since 2008).[7] The second assumption implies that if persons with poor health are more likely (less likely) to move, we would underestimate (overestimate) the effect of housing on health, as healthier (unhealthier) individuals would be overrepresented in our sample. Our strategy would thus suffer from selection bias. We test this assumption by regressing a linear probability model of various health variables (SAH, ADL, and the chronic disease dummy) on a dummy variable indicating whether a person has moved (see Table B.10 in Appendix B, in the Online Supporting Information). Neither poor SAH nor chronic diseases influence moving probabilities. However, individuals with ADL have a 0.2 percentage points decreased probability of moving. If we relate this to the unconditional moving probability of 3.7 percent (0.02/3.7), persons with limitations in daily activities have a 5.4 percent lower likelihood of moving. This changes the composition of our sample and, consequently, our approach tends to overestimate the effect of bad housing on ADL. Hence, causality claims for this health indicator are limited. With regard to the third assumption, concerning changes in neighborhood characteristics over time, we pooled cross-sectional SILC data for 2005–8 and investigated the correlation of three such indicators over time at the lowest possible regional level (NUTS2; see Table B.1). Based on the assumption that the quality of the neighborhood is reflected in a dwelling's market price (Ratcliffe, 2015), we also correlated housing price indicators over time (Table B.1).[8] Both analyses showed highly correlated values over time. In sum, this suggests that for a short- to medium-term study, the use of a non-mover sample is a reasonable strategy to control for absent neighborhood effects and to take the endogeneity of both dwelling and neighborhood into account.

A second strategy applied to the sorting problem in the recent literature is an instrumental variables approach. Bilger and Carrieri (2013) instrument the effects of neighborhoods with the degree of urbanization. For a valid instrumentation, the exclusion restriction has to be fulfilled; that is, urbanization only influences health through its effect on neighborhoods. We doubt that the exclusion restriction holds, as various negative and positive effects of population density on health

[7]http://www.census.gov/newsroom/press-releases/2015/cb15–47.html

[8]We included this variable as control variable in a robustness check. The main results were not affected.

have been documented. For instance, a higher degree of urbanization facilitates the transmission of epidemic diseases (Leon, 2008) and air pollution is higher in densely populated areas (Lagravinese *et al*., 2014). On the other hand, urbanization may also have positive health effects, since the availability of high-quality medical infrastructure is often determined by population density.

Simultaneity

There is also a potential simultaneity problem between socioeconomic control variables, especially income, and health status. The common assumption is that healthy persons are able to earn more income. Bilger and Carrieri (2013) solve the problem by using income from interest and dividends received and income from the rental of property or land as additional instruments to circumvent the endogeneity between income and health. The authors convincingly argue that these income categories are not the result of activities that require (current) good health status. Although these two types of income are widely used instruments (see, e.g., Ettner, 1996; Smith, 1999; Lindahl, 2005), we mistrust the exclusion restriction. While the instrument can solve the issue of simultaneity, it is unclear why these types of income should not influence health. If income is important to health status, it is illogical to argue that money is not neutral and thus to assume that certain types of income influence health while others do not. To fulfill the exclusion restriction, the instrument would imply that an individual buying health care (e.g. additional insurance) does "mental accounting" and purchases additional health care/insurance with current income, but does not spend a single euro from interest and rental income on it, which seems unreasonable.

To address potential simultaneity between the socioeconomic control variables and health, we use lagged values for income and economic status. Lagged variables will resolve simultaneity if no third variable, absent from our regression model, influences health in the current observation period and socioeconomic status in the preceding period (Deaton, 1997). In principle, such factors (e.g. genetics, tastes, and lifestyle choices) could be present in our model, but assuming that these factors are stable over the four-year observation period, we control for them via the fixed effects.

Unobserved Heterogeneity

Finally, inferring causal relationships from cross-sectional data makes the analysis prone to endogeneity due to unobserved heterogeneity. Such factors could include unhealthy consumption patterns and preferences that also influence the decision of how to allocate income between housing and other goods; differences in genetic preconditions shaping how susceptible individuals are to certain diseases; differences in cognitive abilities or coping strategies relating to an awareness of the health-related consequences of bad housing; and cultural and political factors that affect health and housing conditions.

Consequently, we conclude that finding convincing instruments for the research question at hand is very difficult. Thus, we dismiss the IV approach and identify effects of housing on health by applying a two-way fixed-effects model.[9] Estimating fixed-effects panel regression models allows us to control for unobservable, time-invariant person fixed effects. Proceeding in this way avoids bias due to unobserved time-constant factors at the person level related to both health and housing deprivation. As sufficient temporal variation is an important precondition for our identification strategy with fixed effects, we separately regressed all housing quality indicators on individual and time fixed effects. This regression yielded very low R^2 measures between 0.002 and 0.006 (see Table B.2), which indicate a meaningful temporal variation in housing quality. Therefore, we estimate a two-way FE linear probability model to obtain average partial effects at the margins in the fixed-effects specification:

$$Health_{i,t} = \alpha + \beta_1 Housing_{i,t} + \beta_2 X_{i,t} + \beta_3 Z_{i,t-1} + \lambda_t + \mu_i + v_{it}. \quad (1)$$

In regression equation (1), the remaining control variables, as described in Section 3.1, are summarized by the vector $X_{i,t}$. Income and the economic status are summarized in the vector $Z_{i,t-1}$. Finally, to control for common time shocks, we include time fixed effects.

Attrition

We test for attrition bias as SILC is a rotational four-year panel. Each year, one of the four subsamples from the previous year is dropped and a new one added. Attrition bias could occur if the determinants of attrition that also influence health cannot be controlled for in the health equation (Honoré *et al.*, 2008). The use of fixed-effects panel regressions makes it possible to control for time-invariant person fixed effects and a variety of observable socioeconomic variables. Nevertheless, attrition bias could still be an issue after conditioning on this set of variables as a result of the unobservable health status; that is, health-related dropouts. To test for this source of bias, a variable addition test (Verbeek and Nijman, 1992; Jones *et al.*, 2013) was used.[10] The attrition test rejects health-related attrition conditional on the model variables (Table B.3, in online Appendix B).

4. Results

4.1. *Descriptive Statistics*

Figure 1 shows that health and deprived housing conditions vary considerably across European countries. The share of individuals reporting bad or very bad health status in 2008 ranges between approximately 23 percent in Hungary and 3 percent in Ireland (Figure 1(a)). A similar variation can be observed for the housing indicators (Figures 1(b)–(f)). In contrast, in the majority of the countries, only a small fraction of the population reported lacking an indoor flush toilet or a bath or shower in the dwelling (Figures 1(d) and 1(e)). An exception can be

[9]See, for instance, Keese and Schmitz (2014), who also use such a strategy to estimate the causal effects of household debt on health in the absence of suitable instruments.

[10]For similar arguments, see Halliday and Kimmitt (2008).

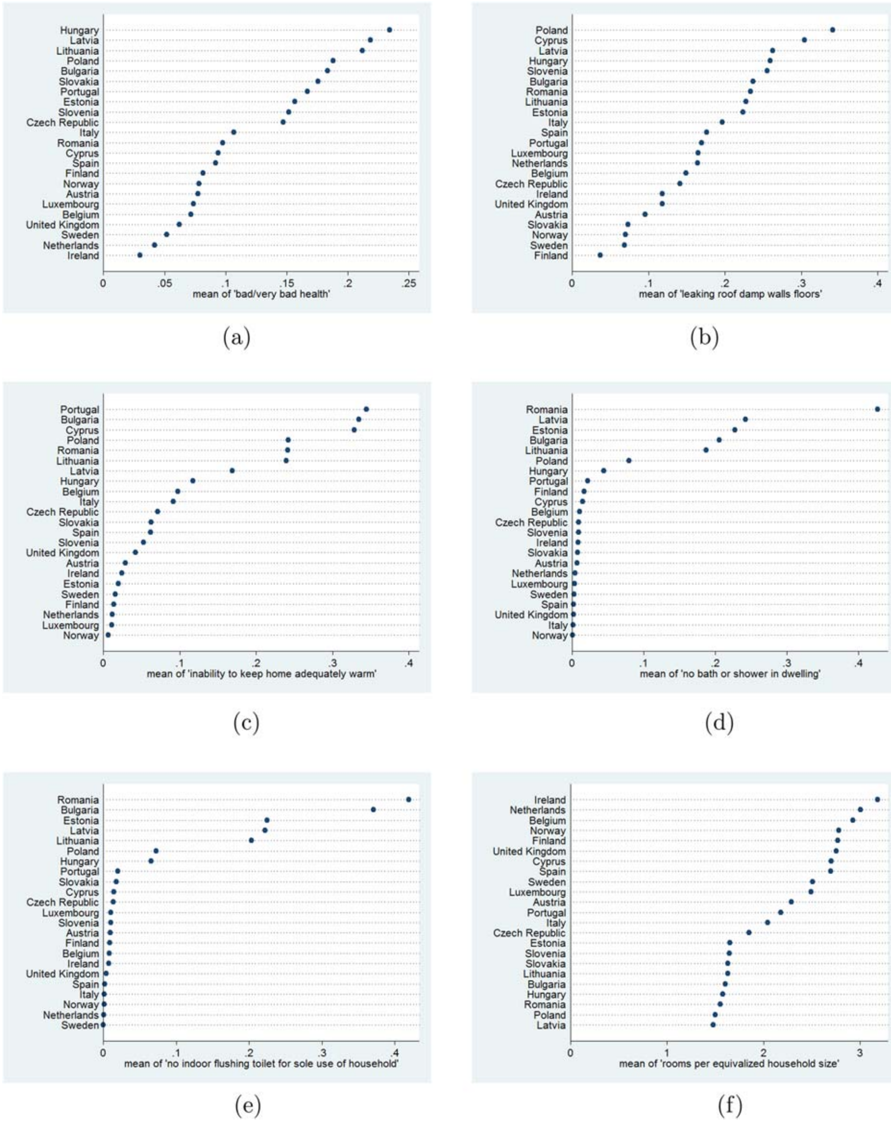

Figure 1. Variation of Variables of Interest (a) Variation in self-assessed health, (b) Variation in leaking roof, damp walls, other, (c) Variation in ability to keep home adequately warm, (d) Variation in bath or shower in dwelling, (e) Variation in indoor flush toilet, (f) Variation in rooms per equivalized household size [Colour figure can be viewed at wileyonlinelibrary.com]

Source: EU-SILC panel data 2005–8.
Note: Unweighted counts.

found in certain Eastern European countries, where the percentage of the population lacking such sanitary facilities for sole household use is relatively high. Crowded living conditions are also more prevalent in these countries (Figure 1(f)). Adjusted for household composition, more than one room is available for each household member in all the countries considered.

TABLE 1
Means of Health and Housing Variables

	(1) SAH	(2) ADL	(3) Chronic
Dwelling problems			
Yes	0.200	0.326	0.392
No	0.115	0.243	0.300
Heating problems			
Yes	0.231	0.332	0.395
No	0.118	0.249	0.308
No bath/shower			
Yes	0.247	0.356	0.392
No	0.125	0.253	0.314
No toilet for sole use			
Yes	0.243	0.336	0.384
No	0.124	0.254	0.314
Overcrowding			
Yes	0.138	0.205	0.256
No	0.131	0.263	0.322
Observations	355,565	355,565	355,565

Source: EU-SILC panel data 2005–8.
Notes: Overcrowding, binary: "Yes" if <1 equivalent household member.

Table 1 demonstrates that individuals living in deprived housing consistently report having poorer health relative to individuals living in decent housing. In the most extreme case, the difference between the mean value of limitations in activities of daily life between persons with and without dwelling problems amounts to 12.3 percent. Across all indicators of poor housing, with the exception of overcrowding, this difference consistently amounts to approximately 10 percent. Conversely, for ADL and chronic diseases, overcrowding is associated with better health. A potential explanation is that living with many persons is beneficial for individuals experiencing difficulties in managing daily living due to health problems and with chronic diseases, as it increases the probability of an available "helping hand."

4.2. *Causal Effects of Housing on Health*

Table 2 presents the regression results of equation (1) for the three dependent variables SAH, ADL, and chronic diseases. Regardless of the health indicator considered, living in a dwelling with a leaking roof, damp walls, or rot, and having limited means to keep the home warm, significantly increases the likelihood of being in poor health. Concretely, living in a dwelling with physical problems increases the likelihood of reporting poor SAH by 1.3 percentage points. Given an unconditional probability of 13.1 percent, this value represents an increase in the likelihood of being in poor health of 9.2 percent. A similar picture emerges for the other health indicators. Facing dwelling problems increases the likelihood of suffering from ADL by 2.2 percentage points and of suffering from a chronic disease by 3.2 percentage points. With respect to the unconditional probability of both health limitations (ADL, 25.9 percent; chronic, 31.8 percent), this value

TABLE 2
Regression Results

	(1)	(2)	(3)
	SAH	ADL	Chronic
Overcrowding	−0.005	0.005	0.004
	(−1.655)	(1.236)	(1.069)
Dwelling problems	0.013***	0.022***	0.032***
	(5.237)	(6.993)	(10.289)
Heating problems	0.012***	0.006	0.013**
	(3.540)	(1.563)	(3.275)
No bath/shower	0.004	0.001	0.003
	(0.332)	(0.110)	(0.221)
No toilet for sole use	0.011	−0.008	0.009
	(0.991)	(−0.655)	(0.701)
X_i	Incl.	Incl.	Incl.
$Z_{i,t-1}$	Incl.	Incl.	Incl.
Observations	355,565	355,565	355,565
Adjusted R^2	0.001	0.001	0.003

Source: EU-SILC panel data 2005–8.
Notes: t statistics in parentheses; standard errors clustered at the household level.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

represents an increase in the probability of reporting health problems of 8.5 percent (ADL) and 10.6 percent (chronic diseases).

Heating problems significantly increase the likelihood of reporting poor SAH by 1.2 percentage points and of reporting chronic illnesses by 1.3 percentage points. This value represents an increase of 9.2 percent in the probability of reporting poor SAH and an increase of 4.1 percent in the probability of suffering from a chronic illness. In contrast, the affordability of adequate heating does not appear to influence ADL. Likewise, overcrowding, the lack of a bath or shower for the sole use of the household, and the unavailability of a toilet for the sole use of the household do not exert statistically significant effects on health indicators. It appears likely that the statistical and economic insignificance of overcrowding is a consequence of our data and methodology, since identification via fixed-effects requires variation within the observation unit. In the case of overcrowding, the within-variation standard deviation is only 0.14, with a mean of 2.09. To identify overcrowding effects, particularly for children, longer observation periods would appear to be necessary.

To sum up, our comparison of housing deprivation indicators and other socioeconomic control variables demonstrates that deprived housing conditions are an important aspect of socioeconomic status in determining health. Other socioeconomic variables—in particular, income and education—do not appear to have direct short-term effects. We also compared the outcomes of the fixed-effects models to simpler linear probability models based on pooled data. The latter showed statistically significant effects for most of the socioeconomic variables (see Table A.4, in online Appendix A). It therefore appears that these relations can be traced back to unobserved time-constant characteristics (e.g. genetic predispositions), whereas housing conditions still have a direct effect on health after controlling for person fixed effects.

4.3. *Extensions*

To provide more insight into the underlying mechanisms driving the results, we use interaction terms to expose differences in housing problems between selected living conditions and sociodemographic variables (Tables B.4–B.9, in online Appendix B). First, we test for a difference in the impact of bad housing on health between owners and renters. This might emerge as owners are themselves responsible for maintaining the dwelling, while renters' landlords are responsible for maintenance. Such a difference could be an indicator for reverse causality, as poor health could influence the inability to sustain the dwelling's upkeep. However, interacting tenure status with housing indicators does not yield statistically significant differences and consequently does not support the assumption of reverse causality between housing and health. Second, overcrowding could interact with deficient housing and thus spur the transmission of diseases. For instance, an increase in interior moisture due to overcrowding can exacerbate already existing dwelling problems. Our models do not provide evidence for such an amplifying effect. A further consideration is that housing problem indicators could differ by gender or age. Both the effects of overcrowding on ADL and of having no toilet for sole use on chronic health problems are more pronounced for women than for men. This could be due to gender-specific toileting routines. We also observe significantly stronger effects of dwelling problems on SAH and on chronic illness among older people (aged 51 and older). Finally, the effects of bad housing on health might differ by the length of exposure. We therefore interact the housing indicators with employment status, as this is an indicator of time spent at home. For instance, it is presumed that retirees and unemployed people spend more time in their dwellings than full-time employees. This interaction reveals that the effect of dwelling problems on self-assessed health is indeed significantly stronger for people in retirement and decreases slightly with the number of hours worked per week.

Beside the hours spent at home, another form of exposure is the accumulation of housing problems over time. As our health indicators differ and the effects of harmful housing are likely to have persistent effects, we suspect that the coefficients will be time-variant for the different health indicators. We expect that enduring dwelling problems will be likely to result in deteriorated ADL and a higher probability of chronic diseases. In contrast, SAH would rather be influenced by more acute dwelling problems. Thus, to investigate housing problems over time we construct three samples, containing individuals who reported suffering from either dwelling or heating problems once, twice, or three times, respectively. However, this considerably reduces the sample size and thus the efficiency of the estimates. In interpreting the effects we therefore emphasize economic significance. Nevertheless, the 95 percent confidence intervals are graphically depicted.

The left-hand plot in Figure 2 depicts the effect of dwelling problems on SAH. It becomes apparent that a unique occurrence of dwelling problems exerts a higher influence on SAH (point estimate of 0.018) than for the whole sample (0.013). This effect becomes nearly zero for dwelling problems experienced on two occasions, but increases to 0.012 for a threefold occurrence. The relatively large

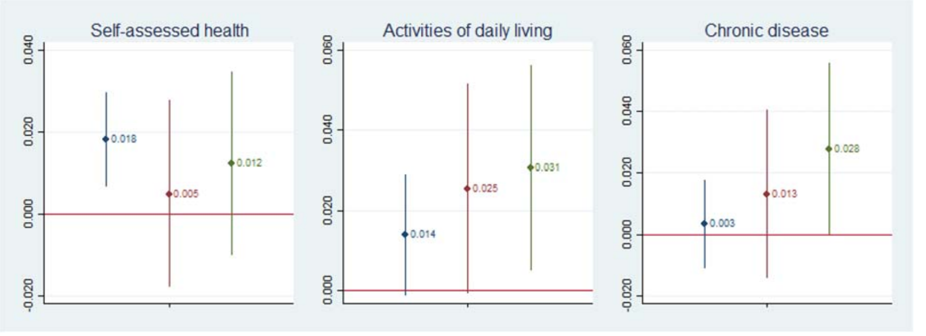

Figure 2. Effects of Accumulated Dwelling Problems on Health [Colour figure can be viewed at wileyonlinelibrary.com]

Source: EU-SILC panel data 2005–8.

Notes: All coefficients result from linear fixed-effects models, as specified in Section 3.2. The first line of each plot stems from the sample of individuals exposed to dwelling problems on a single occasion ($N = 57,\ 803$). The second line stems from the subsample of individuals exposed twice ($N = 39,\ 194$) and the third line from the subsample of individuals exposed three times ($N = 13,\ 725$). The line itself represents the 95 percent confidence interval. A total of 3,642 individuals are exposed to housing problems on four occasions, and 241,201 individuals never experience housing problems. Detailed regression results for all coefficients are available upon request.

effect of non-recurring dwelling problems and the temporary reduction in the case of individuals affected twice may indicate mental health problems due to the onset of deteriorated housing conditions and transitory habituation effects. However, for long-term exposure to poor physical housing conditions, the effect size rebounds.

The central and right-hand plots in Figure 2 depict the effects of dwelling problems on ADL and chronic diseases. Both indicators measure rather severe health problems, and thus the trends in effect size resemble one another. A single occurrence of dwelling problems exhibits a moderate effect on ADL and nearly no impact on chronic diseases. However, the probability of health problems increases for individuals frequently exposed to poor housing conditions.

Concerning heating problems, Figure 3 shows that non-recurring heating problems have no effect on the probability of suffering from a chronic disease. However, heating problems over 2 years increase the probability of chronic disease by 2.2 percentage points. A single or threefold experience of heating problems has almost no effect on SAH, whereas two periods increase the probability of SAH by almost 2 percentage points. Concerning ADL, heating problems show weaker transitory effects compared to dwelling problems. In sum, we can corroborate our expectation that a persistent exposure to poor dwelling conditions affects ADL and chronic diseases more than SAH. A possible avenue for further research would be thus to examine whether people adapt to poor dwelling conditions and alter their level of SAH accordingly.

As a final extension, we tested (1) whether the results of Bilger and Carrieri (2013) for Italy could be generalized to other European countries and (2) how they compare to our longitudinal results. Using 2005 cross-sectional SILC data for Italy and other European countries and the same method (two-stage residual inclusion, 2SRI), we are only able to replicate these findings for chronic diseases.

Figure 3. Effects of Accumulated Heating Problems on Health [Colour figure can be viewed at wileyonlinelibrary.com]

Source: EU-SILC panel data 2005–8.

Notes: All coefficients result from linear fixed-effects models as specified in Section 3.2. The first line of each plot stems from the sample of individuals exposed to dwelling problems on one occasion ($N = 43,581$). The second line stems from the subsample of individuals exposed twice ($N = 23,656$) and the third line from the subsample of individuals exposed to dwelling problems on three occasions ($N = 7,322$). The line itself represents the 95 percent confidence interval. A total of 2,010 individuals are exposed to housing problems four times, and 278,996 individuals never experience housing problems. Detailed regression results for all coefficients are available upon request.

We do not find significant results for SAH and ADL. Moreover, the 2SRI method shows that neighborhood problems are indeed endogenous.[11]

4.4. *Robustness Checks*

We applied four groups of checks to assess the robustness of our main results, which are summarized in Table B.11, in online Appendix B.[12] The first group of checks concerns alterations in coding the variables. We altered the variable of interest by applying an additive housing deprivation index; that is, aggregating the number of problems instead of measuring them as separate variables. The latter revealed that the likelihood of all health variables increases with the number of housing problems. Furthermore, we modified the income variable by replacing equivalized disposable income with a dummy variable for income poverty, taking a value of one if a household receives less than 60 percent of the median income. We also used equivalized disposable income measured in country-specific quintiles. The use of quintiles has the advantage of avoiding a conversion of country-specific currencies and reducing the issue of possible measurement error, while having the household as the unit of measurement limits the endogeneity problem between health and income. Table B.11 shows that these alterations did not impact the point estimates and statistical significance. Finally, we varied the cut-off point of the dependent variables SAH and ADL. In the case of SAH, code "1" refers exclusively to a very bad health status in one model and to either a fair, bad, or very bad general health in another model. For ADL, we also applied a

[11]More details on the replication and all outcomes are presented in Section D of online Appendix A.

[12]Full tables including *t*-statistics are provided in section E of online Appendix A.

stronger cutoff criterion and coded only severely limited persons with "1." This exercise reduced the magnitude of the estimates for dwelling problems and heating problems, but the effects remained statistically significant (columns 1 and 3 in Table B.11).

In the second group of checks, we tested whether our results were driven by countries where housing deprivation is most prevalent. The following countries were in the top five on most of the housing deprivation indicators and were thus excluded from the estimation sample for this robustness check: Bulgaria, Poland, Portugal, Romania, and additionally Latvia, Cyprus, Lithuania and Estonia. Estimates of our housing problem indicators were only marginally affected and remained statistically significant.

The third check was related to the link function in the models. As SAH and ADL are measured on an ordinal scale, we also calculated the effects of housing deprivation on health based on the "blow-up and cluster" (BUC) estimator, as discussed in Baetschmann *et al*. (2015) and Mukherjee *et al*. (2008). The BUC estimator collapses the ordered dependent variable to a binary variable based on a specific rule and provides the estimates in the metric of log(odds) conditional on person and time fixed effects. Concerning the main effects, no substantial differences occur compared to our linear probability specification and to our logit specification (Table B.11). We even found the expected significant negative relationship between the number of rooms and SAH. Logistic panel regressions using fixed effects again confirmed the outcomes of our main specification. For instance, if there are dwelling problems, the odds of a (very) bad SAH increase by a factor of 1.25.

The issue of maintaining their dwelling (as with owners and renters; see Section 4.3) may also pertain to individuals with health problems. Reverse causality between health and housing may emerge if these individuals are not capable of continuously keeping up their home. We argue that this simultaneity issue—if anything—is likely to be relevant for only some types of households (e.g. single persons who cannot rely on other people living in the same household or do not have the financial means to pay for maintenance services) and for more severe health shocks. Thus we also ran separate estimations that excluded (a) persons with severe health problems or (b) single households from our data set. If these simultaneity arguments were true, then the overall effect of housing on health should disappear or be reduced substantially after these sample restrictions. Concretely, we excluded persons assessing their SAH as "very bad" and those individuals with severe limitations in the ADL indicator. Again, none of these sample modifications changed the substance of our results.

5. Discussion and Conclusions

Our analysis provides evidence that bad housing conditions have a direct adverse effect on general health. This result differs from studies on the MTO experiment such as Kling *et al*. (2007) that do not find significant overall effects on adult physical health. Explanations for this could be their smaller test power and a possible selection effect by randomizing treatments only among persons eligible for public housing. Applying for a means-tested, in-kind benefit might be especially challenging for people already in poor health and in need of public housing. In contrast, the data we use are based on a nationally representative probability sample of the European population residing in private households. Differences in outcomes could therefore also simply reflect the limited comparability between housing and neighborhood conditions in deprived areas of U.S. cities and a representative European population.

Our results relate to the findings of the observational studies discussed in Section 2.2 as follows. Unlike Navarro *et al*. (2010), who found overcrowding to be significant, albeit with a small magnitude (OR = 1.02), our results reflect the findings of Pevalin *et al*. (2008) that overcrowding does not have a significant effect on health. However, we were able to corroborate the finding by Navarro *et al*. (2010) that an inability to keep the dwelling warm and structural dwelling problems significantly deteriorate health, as well as the result of Pevalin *et al*. (2008) that health problems increase with accumulated housing problems. In contrast with previous research using observational data, we have strengthened the possibility of claiming a causal effect by taking the possible endogeneity of both dwelling and neighborhood sorting into account. Furthermore, we address the reverse causality of additional socioeconomic control variables with health. By extending the sample beyond single countries, we demonstrate that the relationship between bad housing and health holds across geographic borders, and our significantly increased sample size also facilitated the identification of possibly small effects of bad housing on health. Compared to previous research, we were able to show heterogeneous effects of poor housing on health according to gender, age, and the exposure time to detrimental housing.

From a policy perspective, our findings can justify measures to improve housing conditions for individuals in deprived living conditions, as these have a direct causal effect on health. To offer policy guidance concerning how to implement such measures, further research on the cost-effectiveness of housing policies would be desirable, as these topics are currently under-researched. Recent evidence concerning housing subsidies in the U.S. (Carlson *et al*., 2011) indicates that the effect of the overall level of net benefits is not clear, although it appears likely that the program under study (Section 8 housing vouchers) delivers positive net benefits.

Of course, this paper faces certain limitations. First, regarding inadequate housing, we cannot disentangle the individual causes most responsible for bad housing, as our main variable of inadequate housing in the data set is an aggregate of various items (e.g. mold, dampness, and leaking roof). As the variable is self-reported, measurement error could be an issue if the respondents were uninformed regarding possible problems affecting the quality of their housing; for example, the inability to identify mold and a lack of information about effective remedies. Similarly, we have to assume that the variation generated in our variables of interest is not a result of measurement error. Finally, our estimation method via fixed effects represents an analysis of temporary poor housing. It may therefore underestimate the effects of long-term exposure to poor housing. Nevertheless, in terms of examining short- and mid-term effects, we have been able to provide a novel and more detailed insight into the causal relationship between bad housing and health.

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