Poor housing quality and the health of newborns and young children

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ABSTRACT

This study uses linked administrative data on live births, hospital stays, and census records for children born in Hungary between 2006 and 2011 to examine the relationship between poor housing quality and the health of newborns and children aged 1-2 years. We show that poor housing quality, defined as lack of access to basic sanitation and exposure to polluting heating, is not a negligible problem even in a high-income EU country like Hungary. This is particularly the case for disadvantaged children, 20-25% of whom live in extremely poor-quality homes. Next, we provide evidence that poor housing quality is strongly associated with lower health at birth and a higher number of days spent in inpatient care at the age of 1-2 years. These results indicate that lack of access to basic sanitation, hygiene, and non-polluting heating and their health impacts cannot be considered as the exclusive problem for low- and middle-income countries. In high-income countries, there is also a need for public policy programs that identify those affected by poor housing quality and offer them potential solutions to reduce the adverse effects on their health.

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Rossz lakásminőség és az újszülöttek és kisgyermekek egészsége

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ÖSSZEFOGLALÓ

Tanulmányunk a 2006 és 2011 között Magyarországon született gyermekek adminisztratív adatai alapján vizsgálja a rossz lakásminőség és az újszülöttek, illetve az 1-2 éves gyermekek egészsége közötti kapcsolatot. Ehhez élveszületések, kórházi ellátások és népszámlálási rekordok egymással összekötött adatait használjuk. Megmutatjuk, hogy a rossz lakásminőség, amelyet az alapvető higiéniai feltételekhez való hozzáférés hiányaként és a szennyező fűtésnek való kitettségként határozunk meg, még egy olyan magas jövedelmű európai uniós országban sem elhanyagolható probléma, mint Magyarország. Különösen igaz ez a hátrányos helyzetű gyermekek esetében, akiknek 20-25 százaléka él rendkívül rossz minőségű lakásokban. Megmutatjuk azt is, hogy a rossz lakásminőség szorosan összefügg az alacsonyabb születéskori egészséggel és az 1-2 éves korban fekvőbeteg-ellátásban töltött napok magasabb számával. Ezek az eredmények arra utalnak, hogy az alapvető tisztálkodási és higiéniai feltételekhez, valamint a nem szennyező fűtési módokhoz való hozzáférés hiánya, továbbá ezek egészségügyi következményei nem tekinthetők az alacsony és közepes jövedelmű országok kizárólagos problémájának. A magas jövedelmű országokban is szükség van olyan közpolitikai programokra, amelyek azonosítják a rossz lakásminőség által érintetteket, és potenciális megoldásokat kínálnak számukra az egészségükre gyakorolt káros hatások csökkentése érdekében.

JEL: I10, I14, J13, Q53
Kulcsszavak: születéskori egészség, kora gyermekkori egészség, lakásminőség, alapvető higiéniai körülmények, beltéri légszennyezés

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Abstract

This study uses linked administrative data on live births, hospital stays, and census records for children born in Hungary between 2006 and 2011 to examine the relationship between poor housing quality and the health of newborns and children aged 1-2 years. We show that poor housing quality, defined as lack of access to basic sanitation and exposure to polluting heating, is not a negligible problem even in a high-income EU country like Hungary. This is particularly the case for disadvantaged children, 20-25% of whom live in extremely poor-quality homes. Next, we provide evidence that poor housing quality is strongly associated with lower health at birth and a higher number of days spent in inpatient care at the age of 1-2 years. These results indicate that lack of access to basic sanitation, hygiene, and non-polluting heating and their health impacts cannot be considered as the exclusive problem for low- and middle-income countries. In high-income countries, there is also a need for public policy programs that identify those affected by poor housing quality and offer them potential solutions to reduce the adverse effects on their health.

JEL codes: I10, I14, J13, Q53

Keywords: health at birth, early childhood health, housing quality, basic sanitation, indoor air pollution

1. Introduction

Given that health at birth and in early childhood plays an important role in shaping later life outcomes (Behrman and Rosenzweig 2004; Bharadwaj et al. 2018; Black et al. 2007; Case et al. 2005; Currie 2009; Currie and Almond 2011; Figlio et al. 2014; Flores and Wolfe 2022; Karbownik and Wray 2022; Lambiris et al. 2022; Smith 2009), a large body of research has studied the different factors influencing various indicators of newborns' health and has examined the extent of inequalities. Numerous studies have shown that there are huge disparities in the health status of newborns and young children around the world (Aizer and Currie 2014; Bilsteen et al. 2018; Blumenshine et al. 2010; Case et al. 2002; Coffey et al. 2022; Cook et al. 2013; Costa 2004; Hajdu et al. 2019a; Martinson and Reichman 2016; Mehta et al. 2013; Oberg et al. 2016; Pillas et al. 2014; Szabó and Boros 2023). It is a common worldwide phenomenon that disadvantaged newborns tend to have a lower birth weight and are more likely to be born prematurely. They also have worse early childhood health indicators than their more advantaged peers. A concerning fact is that many of these differences appear to be stable over time rather than decreasing in any significant way (Costa 2004; Hajdu et al. 2019a; Mehta et al. 2013; Oberg et al. 2016).

Reducing the often immense health inequalities in infant and early childhood is important not only for moral and social justice reasons but also for economic reasons. Interventions at younger ages can generate high cumulative benefits by altering developmental trajectories, and they are usually more cost-effective compared to interventions at older ages, especially if they are effectively targeted (Chetty et al. 2016; Heckman 2006; Karoly et al. 2006). Policies that can improve the health of the most vulnerable children not only benefit them but are also likely to generate significant social benefits by reducing (current and future) negative externalities from inequalities.

Lack of access to good quality water, sanitation, and hygiene (WASH) and exposure to polluted air can be an important reason for poor children's lower health status. A large body of literature focuses on these issues and analyzes the impact of low housing quality, access to basic sanitation, poor hygiene, and indoor air pollution (from polluting fuels used for cooking and heating), which are serious problems for hundreds of millions of children. Several studies have concluded that these factors are important contributors to poor health – both at birth and in early childhood – including low birthweight, preterm birth, small for gestational age, respiratory infections, pulmonary diseases, infectious diseases, and infant and child mortality (Alsan and Goldin 2019; Dherani et al. 2008; Duflo et al. 2015; Fink et al. 2011; Freeman et al. 2017;

Fullerton et al. 2008; Geruso and Spears 2018; Harville and Rabito 2018; Headey and Palloni 2019; Ingham et al. 2019; Kinney et al. 2021; Lee et al. 2020; Murray et al. 2020; Padhi et al. 2015; Wolf et al. 2022; Younger et al. 2022; Zhu et al. 2023). Although mortality associated with household air pollution has substantially decreased in the last decades, a recent paper estimated that even in 2018, 320,000 deaths of children could be attributed to household air pollution from the use of solid fuels in low-income and middle-income countries (Frostad et al. 2022). Another study calculated that in children under five years of age, almost 300,000 diarrheal deaths were attributable to inadequate WASH in 2016 (Prüss-Ustün et al. 2019). This figure has only declined slightly by 2019 (Wolf et al. 2023). In addition, 112,000 deaths from acute respiratory infections were attributed to unsafe hygiene in this age group in 2019 (Wolf et al. 2023). Without significant future policy interventions, these figures are unlikely to change much. The prevalence of solid fuel use is expected to remain sizable in the future: a recent study projects that almost one in three people will still be using polluting solid fuels in 2030 (Stoner et al. 2021). Besides, access to safe drinking water and adequate sanitation facilities will continue to be a challenge for many people around the world in the near future (WHO and UNICEF 2021).

These issues are often seen as the exclusive problem of low- and middle-income countries, and although their prevalence is significantly higher in these countries, poor and disadvantaged people in high-income countries also suffer from the consequences of poor sanitation and indoor air pollution (Brown et al. 2023; Deitz and Meehan 2019; Ferguson et al. 2020; Mueller and Gasteyer 2021). Low-income households and minorities, like the Roma in Europe, especially lack access to adequate WASH (Anthonj et al. 2020), and Hungary is no exception (Kósa et al. 2011).

In this paper, we advance the literature on the effect of inadequate WASH and indoor air pollution. We construct a large and unique, individual-level dataset of children born in Hungary between 2006-2011 by linking three administrative datasets: birth records, population census, and administrative data of inpatient care. We examine six indicators of health at birth and three indicators of inpatient care in early childhood and analyze their relationship with an index of poor housing quality. This housing quality index includes the lack of access to water, bathrooms, or toilets, exposure to polluting heating, and adobe houses. In our analysis, we control for many aspects of parental background, including education, age, ethnicity, labor market status, occupation, and marital status, along with the mother's pregnancy history. Importantly, we also control for the unobserved characteristics of small geographic areas that

uniformly influence the health of the newborns and young children living there by introducing census tract fixed effects. We find that exposure to poor housing quality in the fetal period is associated with significantly lower birth weight, shorter gestation, lower APGAR score, and a higher chance of being an SGA infant. In addition, poor housing quality is also correlated with a higher number of days spent in inpatient care at the age of 1-2 years, even when controlling for indicators of health at birth.

Our analysis contributes to the existing literature in at least three ways. First, unlike the previous literature, we use linked administrative data. One of the advantages of this dataset is that the number of observations is exceptionally large compared to usual survey data (more than 250,000), therefore the statistical power of our study is high, and relatively low-prevalence phenomena can be studied (such as the health impacts of extremely low-quality housing in high-income countries). Administrative data are also usually more accurate than survey data as they result from standard measurements and data collection, and they are not affected by the accuracy of individuals' recalls and misreporting. Second, we provide evidence on the relationship between housing quality and the health of newborns and young children in a high-income country. Most of our knowledge is from developing countries, but as we noted earlier, poor housing quality is also experienced by many disadvantaged people in high-income countries. Third, we examine both health at birth and in early childhood, so we can gain some insight into which periods are more affected by poor housing quality. Previous studies could not make such comparisons because they focused on the health of either newborns or young children.

The rest of the paper proceeds as follows. Section 2 describes the data and methods used in the paper. Section 3 presents the results. Section 4 discusses the implications of the findings and concludes.

2. Data and methods

2.1. Live birth records

The first administrative dataset of this analysis is the live birth registry of the Hungarian Central Statistical Office (HCSO). It covers all live births in Hungary from 1970 onwards, and, among others, it contains information on several birth-related variables: the date of birth, gestational age, birth weight, birth length, and APGAR score. It also includes information on the mother's and father's age, education, labor market status, occupation (Hungarian standard classification of occupations), and the municipality of residence. The marital status and the pregnancy history

of the mother are also known (number of previous live births, induced abortions, and spontaneous pregnancy losses).

We defined six outcome variables that capture a newborn's health at birth: (i) birth weight (measured in grams), (ii) an indicator of low birth weight (birth weight <2500 grams), (iii) gestation length (measured in completed weeks), (iv) an indicator of preterm birth (pregnancy length <37 weeks), (v) low APGAR score[1] (≤8), and (vi) an indicator of small for gestational age.

2.2. Population census

Information on housing quality comes from the 2011 population census of the HCSO, which covers the entire population of Hungary. The 2011 census was conducted in October 2011, the reference date was October 1st, 2011. In addition to the information on individuals, the census also included a separate housing questionnaire, which measured both the characteristics of the dwelling and how long the respondent had lived there. We defined six binary indicators of poor housing quality: (i) lack of flush toilet, (ii) lack of a bathroom, (iii) lack of piped water, (iv) lack of hot running water, (v) adobe house, (vi) polluting heating. Heating with solid fuels (wood or coal) was considered to be a polluting heating method if each room was heated separately. These six variables were summed to create an index of poor housing quality, ranging from 0 to 6. A value of 0 means that the dwelling is not considered to be of poor quality in any of the aspects assessed, whereas a value of 6 indicates the worst quality dwellings, i.e., the dwelling is considered to be of poor quality according to all the indicators assessed.

Beyond housing quality, the Roma ethnicity of the parents is also derived from the 2011 census. The Roma are one of the largest and poorest ethnic minorities in Europe. In Hungary, it is estimated that more than 8 percent of the total population is Roma (Pénzes et al. 2019). They face poverty, multiple disadvantages, and discrimination (Hajdu et al. 2019b; Janky 2004; Kertesi and Kézdi 2011a, 2011b; Scharle 2021; Váradi 2014). Ethnicity was measured by two questions, allowing for multiple identities. All mothers and fathers were categorized as Roma if they identified themselves as Roma in either of the questions on ethnicity. Information from the 2011 census also allows us to take into account the characteristics of the geographical micro-environment of the children. The smallest unit of the neighborhood in the Hungarian census is

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[1] APGAR score evaluates the health condition of the newborns using five criteria (Appearance, Pulse, Grimace, Activity, Respiration) and ranges from 0 to 10.

the census tract containing around 250 individuals on average. Each census respondent belongs to a census tract.

2.3. Inpatient care

Data on inpatient care are obtained from the medical records of the Hungarian National Healthcare Services Center (NHSC). For the period 2008-2017, we have information on all inpatient stays for children born between 2008 and 2016 in public healthcare.[2] Inpatient care events can be transformed into a panel database using an anonymized identifier. For each event, the patient's sex, date of birth, place of residence (zip code), and the date of the care event are known. Specific health conditions can be identified by the International Classification of Diseases (ICD) codes. We focus on inpatient care at the age of 1-2 years, as the anonymized identifier may have changed during the first few weeks/months of life due to administrative reasons.

From the inpatient care records, we created three indicators of early childhood health: (i) the number of days spent in inpatient care for any disease (ICD codes: A00-Z99), (ii) the number of days spent in inpatient care for respiratory diseases (ICD codes: J00-J99), and (iii) the number of days spent in inpatient care for infectious diseases (ICD codes: A00-B99). Each of these shows the total number of days spent in hospitals over the two years from age 1 to the end of age 2.

2.4. Data linkage and sample selection

The population used to study the relationship between housing quality and health at birth consists of singleton births in the live birth dataset between September 2006 and August 2011. In the first step, we excluded births with missing information on health at birth. Next, the birth records were linked to the census data. Neither birth records nor census records contain any personal identifiers, such as social security numbers, that would help link them. The main variables used for the linkage are the exact date of birth of the child and mother, the sex of the child, and the place of residence of the mother at the time of the child's birth. We found some additional matches when we narrowed down the multiple matches by including other variables (father's birth date, and parents' education). In the linked dataset, we excluded records where moving into the census dwelling occurred after the start of pregnancy. Finally, records where

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[2] The health care system in Hungary is single-payer system. The vast majority of individuals are insured, inpatient and outpatient care is financed by compulsory health insurance and is free of charge. Total opt-out is prohibited, but people can use private care for certain services. This is typically the case for outpatient services, but even there it is a small number of cases. Inpatient care in private care is most common for obstetric care. Private inpatient care for young children is practically non-existent.

any item of the housing quality index was missing were excluded. The number of observations excluded at each step of the sample selection is reported in Table A1 (Online Appendix). While problems of missing key variables only occur in the case of 1-3% of observations, we lose around 10% of the sample at linking the birth registry to the census and around 30% when we exclude those that moved since the beginning of their pregnancy. This, however, is a necessary step as we want to ensure that the housing conditions captured in the census characterize the mother's living conditions while pregnant. The final sample covers 253,929 children.

When we analyze associations with early childhood health, we have to work with a narrower sample that includes children born between January 2008 and August 2011. Beyond the data linkage steps described above, in this case, we require successful linkage to the inpatient care data, which results in excluding around 27% of the relevant original sample (Table A2, Online Appendix). The main reason for this relatively high failure rate is that we were only able to use the following information to link inpatient care data: date of birth, sex, and place of residence. The final sample, which is used to examine the relationship between housing quality and early childhood health, consists of 107,934 children.

We can form an understanding of the introduced bias by examining the evolution of the key outcome variables over the steps of the sample selection, which we report in Table A3 (Online Appendix). The magnitudes of the induced differences are small. For instance, the final analysis sample has an around 20 grams higher mean birth weight than the starting singleton dataset, so the final analysis sample contains information on children with slightly better health outcomes on average. Additionally, the observations for the analysis of early childhood health are even closer concerning health outcomes to the original sample: in terms of birth weight, the difference is only around 10 grams. As we control for several observable characteristics in the regressions and the selection does not seem to impact the key outcomes substantially, it is likely that our results are not far from what we would estimate for the entire population. Nevertheless, we re-estimated our main results with inverse probability weighting in our robustness checks. In this exercise, the weights are derived from a probability model that runs on the baseline dataset (singleton births in the live birth registry) and predicts the probability of being included in the final analysis samples with all information available in the birth records.

Table 1 shows the descriptive statistics of the outcome variables and the index of poor housing quality for the two analysis samples of our study. The average birth weight is somewhat more than 3300 grams, while the average gestation length is nearly 39 weeks. Around 6% of the newborns were born with a low birth weight (<2500 grams) or premature (before the 37th week

of pregnancy), 5% of the sample have a low APGAR score, and the share of SGA newborns is almost 10%. The children in the early childhood health sample spent, on average, nearly two days in hospital between the ages of 1-2 years. Nearly one hospital day was for respiratory illnesses and 0.6 days for infectious diseases. The average score of the poor housing quality index is 0.5 in the health at birth sample and slightly higher (0.6) in the early childhood health sample.

Table 1: Descriptive statistics

Variable	Mean	SD	N
Birth weight	3327	541	253,929
LBW	0.057	0.233	253,929
SGA	0.098	0.297	253,929
Gestation length	38.85	1.71	253,929
PTB	0.065	0.247	253,929
Low APGAR	0.052	0.222	253,929
N of days in inpatient care (any diseases)	1.90	7.39	107,934
N of days in inpatient care (respiratory diseases)	0.90	4.21	107,934
N of days in inpatient care (infectious diseases)	0.59	3.27	107,934
Poor housing quality index (health at birth sample)	0.52	1.20	253,929
Poor housing quality index (early childhood health sample)	0.61	1.27	107,934

2.5. Methods

The association between poor housing quality and the health of newborns and young children is estimated by the following regression:

$$H_{iymc} = \beta PHQI_{iymc} + \gamma X_{iymc} + \rho_{ym} + \tau_c + \varepsilon_{iymc} \tag{1}$$

where H is the health of child *i*, born in year *y* and month *m*, and living in census tract *c*. PHQI is the index of poor housing quality (ranging from 0 to 6), and β shows how one higher value of the index is associated with lower/higher health. When the outcome variables are health at birth, β indicates the influence of housing quality during pregnancy. When the outcome variables are early childhood health, β indicates the joint influence of housing quality during pregnancy and early childhood.

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X denotes the vector of control variables. It includes the sex of the child, the mother's and father's age (-17, 18-24, 25-29, 30-34, 35-39, 40-), education (primary, vocational, high school, tertiary), labor market status (employed, unemployed, on maternity leave, student, other), Roma ethnicity, and occupation (Hungarian standard classification of occupations codes)[3], as well as the marital status (single, married, divorced, widowed), the number of previous live births (0, 1, 2, 3, 4, 5+), induced abortions (0, 1, 2, 3+), and spontaneous pregnancy losses (0, 1, 2, 3+) of the mother. Missing dummies for all control variables are also included. Year-by-month fixed effects (ρ) control for those unobserved factors that uniformly affect the health of children born in the same year and month. Census tract fixed effects (τ) control for all unobserved location-specific factors that do not change over the years studied and affect the health of children living in the same small neighborhood (e.g., quality and availability of outpatient and GP care in the neighborhood, quality of drinking water, etc.).

3. Results

3.1. Prevalence of low housing quality

Poor-quality housing is not an uncommon phenomenon among children in Hungary (Figure 1). One-quarter of the children in the health at birth sample live in a home that does not meet at least one of the basic quality criteria we examined, and 4% of children live in a home that scores 5 or 6 on the poor housing quality index. The latter children lack access to basic sanitation facilities such as piped water, flush toilets, or bathrooms, and their homes are characterized by a heating system that is considered polluting. Importantly, these rates are significantly worse for disadvantaged children. 19% of children of mothers with at most primary education live in very poor-quality housing (index scores 5-6), while only 29% live in a home that is not considered poor quality on any of the indicators assessed. For children of Roma mothers, these figures are 27% and 19%, respectively.[4] These deprived groups represent significant segments of society. Children of mothers with at most primary education account for 16% of the sample, while children of Roma mothers account for 6%. These results clearly show that poor-quality housing can be quite widespread among the poorest members of society, even in a developed country like Hungary. This also means that the potential impacts should not be considered as a marginal issue but as a substantial public policy problem.

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[3] The most detailed occupation categories were considered. Dummy variables for all four-digit occupation coded were included into the regressions. The classification system distinguishes nearly 500 occupations.
[4] The results are qualitatively similar when examining the distributions in the early child health sample (Figure A1, Online Appendix).

Figure 1: Distribution of observations by values of the index of poor housing quality
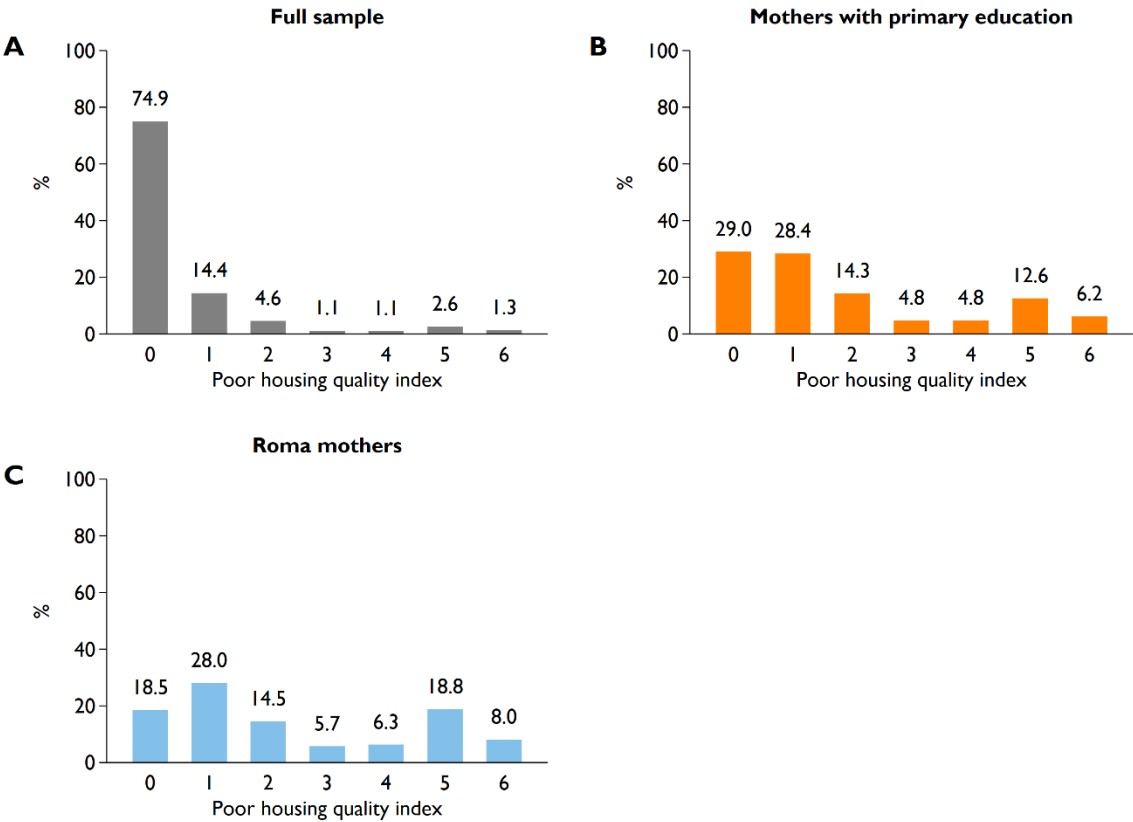
Notes: In the health at birth sample. (A) N=253,929, (B) N=44,388, (C) N=17,552.

Figure A2 in the Online Appendix shows the prevalence of the components of low housing quality. Polluting heating and homes made of adobe are the two most common quality problems, affecting 17.5% and 13.1% of children respectively. However, the prevalence of the other components is also not negligible, ranging from 3.1% to 6.7%.

3.2. Health at birth

Table 2 summarizes the estimated associations between poor housing quality and health at birth estimated using Eq. (1). The results show overall that the poorer the housing quality, the worse the health of newborns. A one-point higher index value is associated with a 24-gram lower birth weight and a 0.64 percentage-point increase in the chance of being born with a low birth weight. In terms of gestation length, a one-point higher index value of poor housing quality is associated with a 0.01-week shorter pregnancy length and a 0.18 percentage point higher chance of preterm

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birth. A one-point higher index value is also associated with a 1.4 and 0.1 percentage point higher chance of being born as a newborn with SGA and a low APGAR value, respectively. These values are especially substantial when comparing children with minimum (0) and maximum (6) index values. The difference is 146.3 grams for birth weight, 3.8 percentage points for LBW, 8.4 percentage points for SGA, 0.06 weeks for gestation length, 1.1 percentage points for PTB, and 0.7 percentage points for low APGAR.

Table 2: Housing quality and health at birth

	(1) Birth weight	(2) LBW	(3) SGA	(4) Gestation length	(5) PTB	(6) Low APGAR
Poor housing quality index	−24.39***	0.0064***	0.0140***	−0.0106**	0.0018**	0.0011*
	(1.37)	(0.0007)	(0.0010)	(0.0046)	(0.0007)	(0.0006)
N of obs.	253,929	253,929	253,929	253,929	253,929	253,929
R-squared	0.128	0.070	0.082	0.071	0.057	0.275
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes	Yes	Yes	Yes

Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The sensitivity of the results is explored by a series of robustness tests: different location fixed effects, the inclusion of additional control variables, weighting, and the use of a narrower sample. First, we experimented with ZIP code fixed effects instead of census tract fixed effects (Table A4, Online Appendix). Second, we added further control variables that describe the household composition and characteristics in the 2011 census (Table A5, Online Appendix). These were the number of household members of different ages, the proportion of employed and unemployed persons among 25-59-year-olds, the proportion of tertiary and secondary education among 25-59-year-olds, the proportion of people speaking foreign languages (English, German) among 25-59-year-olds, the proportion of people with long-lasting disease or impairment among 25-59-year-olds, and floor space per inhabitant in the dwelling. These additional control variables help us to capture more accurately those permanent socioeconomic circumstances of the children's household that may have shaped their health at birth and may be correlated with poor housing quality. Third, we re-estimated the regressions with weights that represent the inverse probability of being included in the final analysis samples (Table A6, Online Appendix). Finally, we restricted the sample to children born between September 2008 and August 2011 (Table A7, Online Appendix). In this way, we were trying to ensure that housing quality measured in 2011 describes as accurately as possible the housing conditions in the fetal period. Due to housing renovations, the housing conditions in the fetal period may, in some cases, differ from the 2011 situation, but by narrowing the time window this risk is reduced. The main results are robust, none of these changes alter the conclusions. Poor housing quality is associated with lower health at birth in all specifications.

Next, we examined the potential nonlinearity of the relationship between poor housing quality and the indicators of health at birth. The seven values of the index of poor housing quality are grouped into four categories to ensure that the categories have a sufficient number of observations and that the standard errors are not too large. The categories are 0, 1, 2-4, and 5-6 index values. Figure 2 summarizes these results. We can see that the estimated relationships can be considered mostly linear. Even at low index values, the health indicators of newborns are worse, and the marginal effects appear to be roughly constant. For some outcome variables, however, the estimates are quite noisy, so the coefficients cannot be considered statistically significant. Nevertheless, the general trend still holds in these cases as well.

Figure 2: Housing quality and health at birth
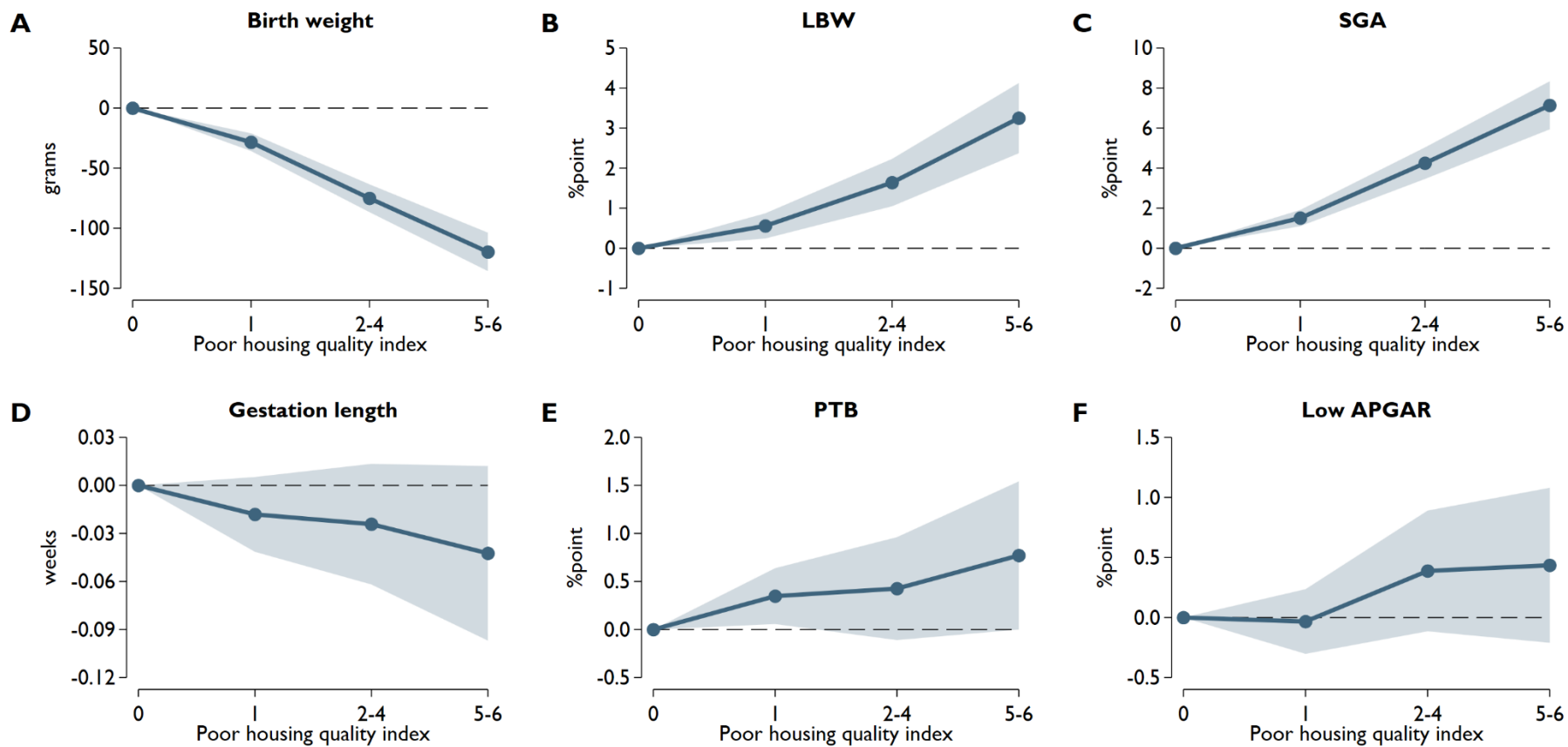
The reference category is 0. Shaded areas represent 95% confidence intervals. Control variables, year-by-month fixed effects and census tract fixed effects are included.

3.3. Early childhood health

The relationship between poor housing quality and early childhood health is summarized in Table 3. The results show that children living in poor-quality homes spent more time in hospitals than children living in good-quality homes. A one-point higher value of the index of poor housing quality is associated with 0.11 more days spent in inpatient care at age 1-2 years. The results in Column 2 and Column 3 of Table 3 suggest that this overall increase is mainly due to an increase in hospital stays for respiratory and infectious diseases. A one-point higher index value is associated with 0.07 and 0.03 more hospital days for respiratory and infectious diseases, respectively.

Table 3: Housing quality and early childhood health

|	(1)	(2)	(3)
	Any diseases	Respiratory diseases	Infectious diseases
Poor housing quality index	0.108***	0.067**	0.034**
	(0.036)	(0.026)	(0.015)
N of obs.	107,934	107,934	107,934
R-squared	0.081	0.092	0.077
Controls	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes

The dependent variables are the number of days spent in inpatient care at the age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

As earlier, the robustness of the results is tested by using alternative location fixed effects (Table A8, Online Appendix), including further control variables (Table A9, Online Appendix), and applying weights that correct for the non-random chances of being selected in the sample (Table A10, Online Appendix). The main conclusions remain intact in all these specifications.

In addition, a new specification is estimated in which indicators of health at birth are controlled for (Table A11, Online Appendix). Since the estimated coefficients in this specification are only slightly lower than in the baseline regressions, it can be concluded that the association between poor housing quality and early childhood health is not simply due to worse health at birth but that the exposure to poor hygiene and sanitation in the early years plays an independent role.

Examining the potential nonlinearity of the relationship between poor housing quality and early childhood health, we find that the relationship is rather nonlinear (Figure 3). Large differences are observed between children living in very poor-quality homes (index score 5-6) and children living in good-quality homes (index score 0). The difference in hospital days for any disease is 0.7 days, whereas for respiratory and infectious diseases, it is 0.4 and 0.2 days, respectively. However, the early childhood health indicators of children with index scores of 1-4 are not particularly different from those of children with an index score of 0.

Figure 3: Housing quality and early childhood health
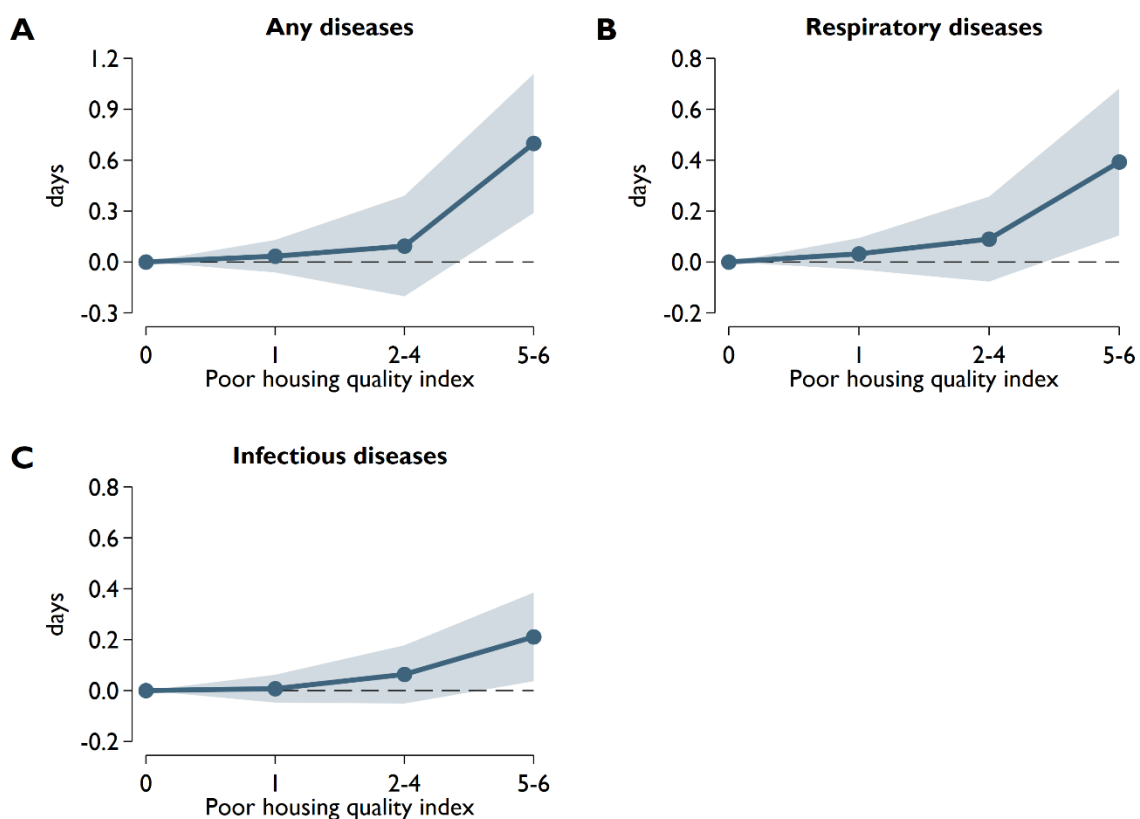
The dependent variables are the number of days spent in inpatient care at age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. The reference category is 0. Shaded areas represent 95% confidence intervals. Control variables, year-by-month fixed effects and census tract fixed effects are included.

4. Discussion

By linking birth certificates, census records and administrative data of inpatient care for children born in Hungary between 2006-2011, this paper addressed the question of how poor housing quality is related to health at birth and in early childhood. Unlike most of the previous

literature, it used data from a high-income country and showed that although the average standard of living is high in Hungary, poor housing quality is not at all a marginal problem, especially among disadvantaged children. It is worth pointing out that the index of poor housing quality includes, among other things, the lack of access to basic sanitation requirements such as a bathroom, running water, or a flush toilet in the home. One might think that these problems were almost non-existent in the 2010s in a member state of the European Union – especially since adequate housing was recognized as a fundamental human right in the Universal Declaration of Human Rights as early as 1948 – but we showed that the vast majority of poor people have low-quality housing on at least one criterion. In fact, a fifth of children of mothers with at most primary education and a quarter of children of Roma mothers live in extremely poor-quality homes, characterized by a lack of piped water, flush toilets, bathrooms, and polluting heating.

We showed that poor housing quality is associated with lower health at birth and a higher number of days spent in inpatient care at the age of 1-2 years. Importantly, the estimated health differences are especially immense when comparing children with minimum and maximum index values of housing quality. Direct comparisons of our results with previous literature are difficult because they usually examine different indicators of housing quality, and early childhood health indicators also differ. However, the importance of housing quality is indicated by the fact that the birth weight and LBW differences (between children with low and high index scores) are very similar to the black-white differences (adjusted for socio-economic and behavioral factors) reported in the literature (Lhila and Long 2012; Morisaki et al. 2017).

Housing quality seems to be more important for some outcomes than for others. Calculating the health differences, in terms of standard deviation, between children living in the worst-quality homes and children living in good-quality homes reveals that the difference is particularly large for birth weight, LBW, and SGA. For these variables, the estimated differences are between 0.16-0.28 standard deviation (Table A12, Online Appendix). For gestation length, PTB, and low APGAR the differences are around 0.03-0.04 standard deviation, whereas for the indicators of early childhood health, they are 0.06-0.10 standard deviation (Table A13, Online Appendix).

It is worth pointing out that the relationship between housing quality and children's health was examined while controlling for local neighborhoods. The census tract fixed effects allowed us to control for any unobserved, place-specific factors that uniformly affect the health of all children living in the same small area. This means that our estimates do not include the impact of exposure to poor-quality housing in the neighborhood, which can also have a significant

impact on the health of newborns and young children (Diez Roux and Mair 2010; Ellen et al. 2001; Shaw 2004).

Although at first glance the recommendations and policy conclusions from the results seem clear, i.e. that the housing conditions of the people affected need to be improved, many questions remain about how to do this. It is important to consider whether, once a dwelling has been renovated and basic sanitation needs have been met, without other changes, residents will be able to pay the increased overhead costs. It may also not be clear whose housing conditions should be improved, as in most cases low-quality housing is geographically clustered. Improving all the affected homes can be extremely costly, while selective refurbishment can lead to tensions within the community, creating external costs that may not have been anticipated. Furthermore, access to higher quality housing is not only available through renovation but also through moving. In this case, the potential impact of changes in the environment and the social network must also be taken into account. These are social policy dilemmas that are not easy to answer and solve. Programs aimed to improve housing conditions for the most deprived require careful planning and considerable expertise. However, it is also worth considering that investments in early childhood health are likely to pay off many times over in later life and can therefore significantly reduce the future costs of social security.

Our findings, based on high-quality administrative data, provide important evidence on the relationship between housing quality and the health of infants and young children, but they have limitations. Most importantly, we could estimate correlations, not causal relationships. Although we controlled for a number of factors, ranging from several characteristics of family background to time-invariant unobserved characteristics of the geographic microenvironment, which allow us to reasonably assume that the causal relationship may not be very different from the results presented here, there may still remain confounders that could be behind the observed relationship. Such factors may include health-related behaviors such as women's smoking, alcohol consumption or diet during pregnancy, the frequency of use of antenatal care, family members' smoking, or young children's dietary habits. Unfortunately, our data do not include such information. A finer measurement of housing quality would also be very useful. In developed countries, damp, moldy, or drafty dwellings may be an even more common problem than the indicators examined here. Temperature and humidity in the home may also be relevant for health. Finally, we would like to point out that although our study examined the relationship between housing quality and children's health, the effects of housing quality may be much broader than this. The lack of basic hygiene facilities and polluting heating can also affect

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outcomes, partly through health and partly independently, such as learning or general well-being, which may also have consequences for later adult life.

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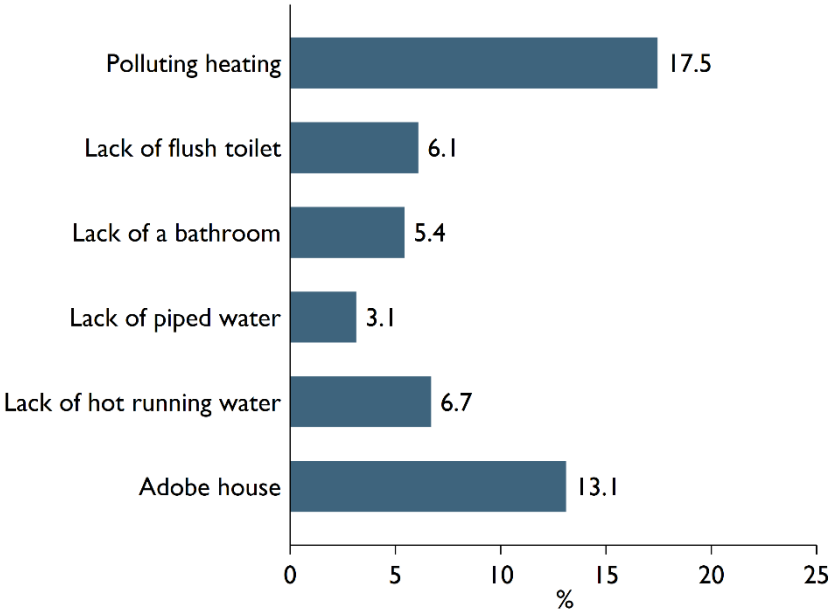
Figure A1: Distribution of observations by values of the index of poor housing quality in the early childhood health sample
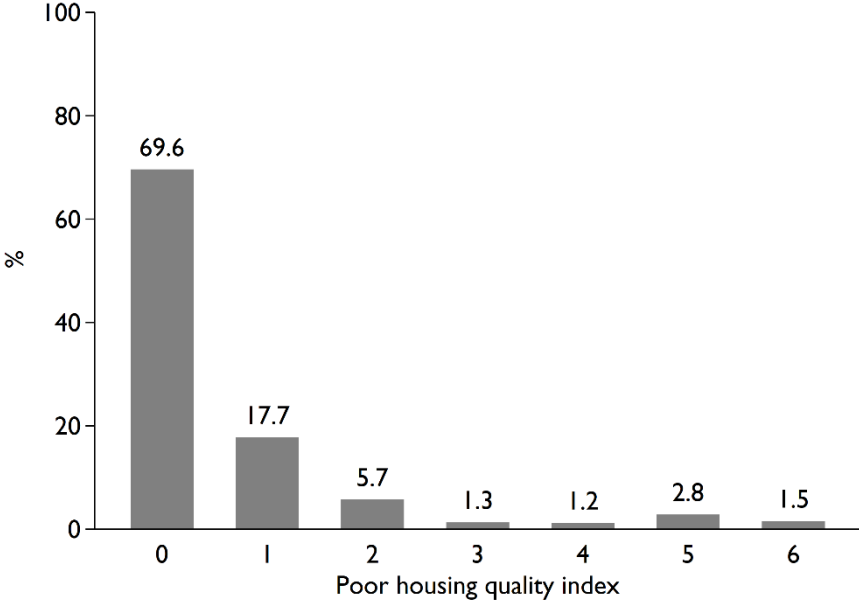
Notes: N=107,934.

Figure A2: Prevalence of the components of low housing quality

Notes: In the health at birth sample. N= 253,929.

Table A1: N of observations by steps of sample selection, health at birth analysis sample

	N of observations	%
0. Total number of singleton births (2006/09-2011/08)	456,624	100.00%
1. Health-at-birth missing	−4,676	−1.02%
2. Unsuccessful link to Census	−44,480	−9.74%
3. Moved in after conception	−140,032	−30.67%
4. Housing quality indicators missing	−13,507	−2.96%
Final sample	253,929	55.61%

Table A2: N of observations by steps of sample selection, early childhood health analysis sample

	N of observations	%
0. Total number of singleton births (2008/01-2011/08)	330,627	100.00%
1. Health-at-birth missing	−2,935	−0.89%
2. Unsuccessful link to Census	−32,227	−9.75%
3. Moved in after conception	−88,447	−26.75%
4. Housing quality indicators missing	−10,290	−3.11%
5. Early childhood health missing	−88,794	−26.86%
Final sample	107,934	32.65%

Table A3: Mean health outcomes at birth by steps of sample selection

Outcome	Singleton births full sample (N = 456,385)	Health at birth analysis sample (N = 253,929)	Early childhood health analysis sample (N = 107,934)
Birth weight	3306 (546)	3327 (541)	3317 (545)
LBW	0.063 (0.243)	0.057 (0.233)	0.061 (0.238)
SGA	0.106 (0.307)	0.098 (0.297)	0.102 (0.303)
Gestation length	38.8 (1.7)	38.8 (1.7)	38.8 (1.7)
PTB	0.068 (0.252)	0.065 (0.247)	0.068 (0.251)
low APGAR	0.054 (0.226)	0.052 (0.222)	0.056 (0.230)

Notes: the table reports the evolution of the key health outcomes' mean and standard deviation at different steps of sample selection. Standard deviations are in parentheses.

Table A4: Housing quality and health at birth, ZIP code fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Birth weight	LBW	SGA	Gestation length	PTB	Low APGAR
Poor housing quality index	−24.76***	0.0066***	0.0141***	−0.0103**	0.0018***	0.0011*
	(1.23)	(0.0007)	(0.0010)	(0.0041)	(0.0006)	(0.0007)
N of obs.	253,929	253,929	253,929	253,929	253,929	253,929
R-squared	0.111	0.053	0.065	0.053	0.040	0.260
Controls	Yes	Yes	Yes	Yes	Yes	Yes
ZIP code FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes	Yes	Yes	Yes

Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A5: Housing quality and health at birth, additional controls

	(1)	(2)	(3)	(4)	(5)	(6)
	Birth weight	LBW	SGA	Gestation length	PTB	Low APGAR
Poor housing quality index	−22.44***	0.0063***	0.0129***	−0.0122**	0.0021***	0.0089
	(1.40)	(0.0007)	(0.0010)	(0.0047)	(0.0007)	(0.0006)
N of obs.	253,929	253,929	253,929	253,929	253,929	253,929
R-squared	0.129	0.071	0.082	0.072	0.057	0.275
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes	Yes	Yes	Yes

Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Additional controls: the number of household members of different ages, the proportion of employed persons among 25-59-year-olds, the proportion of tertiary and secondary education among 25-59-year-olds, the proportion of people speaking foreign languages (English, German) among 25-59-year-olds, the proportion of people with long-lasting disease or impairment among 25-59-year-olds, and floor space per inhabitant in the dwelling. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A6: Housing quality and health at birth, weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)
	Birth weight	LBW	SGA	Gestation length	PTB	Low APGAR
Poor housing quality index	−24.64***	0.0062***	0.0141***	−0.0125**	0.0018**	0.0010
	(1.41)	(0.0008)	(0.0011)	(0.0048)	(0.0007)	(0.0007)
N of obs.	253,929	253,929	253,929	253,929	253,929	253,929
R-squared	0.135	0.075	0.086	0.077	0.061	0.282
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes	Yes	Yes	Yes

Inverse probability weights are applied to account for selection. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A7: Housing quality and health at birth, narrower sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Birth weight	LBW	SGA	Gestation length	PTB	Low APGAR
Poor housing quality index	−23.00***	0.0059***	0.0137***	−0.0042	0.0015*	0.0009
	(1.71)	(0.0010)	(0.0013)	(0.0056)	(0.0007)	(0.0006)
N of obs.	164,943	164,943	164,943	164,943	164,943	164,943
R-squared	0.145	0.086	0.102	0.087	0.073	0.276
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes	Yes	Yes	Yes

Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A8: Housing quality and early childhood health, ZIP code fixed effects

	(1) Any diseases	(2) Respiratory diseases	(3) Infectious diseases
Poor housing quality index	0.113***	0.067**	0.036**
	(0.038)	(0.025)	(0.016)
N of obs.	107,934	107,934	107,934
R-squared	0.053	0.069	0.049
Controls	Yes	Yes	Yes
ZIP code FE	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes

The dependent variables are the number of days spent in inpatient care at the age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A9: Housing quality and early childhood health, additional controls

	(1) Any diseases	(2) Respiratory diseases	(3) Infectious diseases
Poor housing quality index	0.099***	0.063**	0.031**
	(0.036)	(0.027)	(0.015)
N of obs.	107,934	107,934	107,934
R-squared	0.081	0.092	0.077
Controls	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes

The dependent variables are the number of days spent in inpatient care at the age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Additional controls: the number of household members of different ages, the proportion of employed persons among 25-59-year-olds, the proportion of tertiary and secondary education among 25-59-year-olds, the proportion of people speaking foreign languages (English, German) among 25-59-year-olds, the proportion of people with long-lasting disease or impairment among 25-59-year-olds, and floor space per inhabitant in the dwelling. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A10: Housing quality and early childhood health, weighted regressions

	(1)	(2)	(3)
	Any diseases	Respiratory diseases	Infectious diseases
Poor housing quality index	0.091**	0.061**	0.031*
	(0.038)	(0.030)	(0.016)
N of obs.	107,934	107,934	107,934
R-squared	0.090	0.099	0.082
Controls	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes

Inverse probability weights are applied to account for selection. The dependent variables are the number of days spent in inpatient care at the age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A11: Housing quality and early childhood health, controls for health at birth

	(1)	(2)	(3)
	Any diseases	Respiratory diseases	Infectious diseases
Poor housing quality index	0.095**	0.062**	0.031**
	(0.036)	(0.026)	(0.015)
N of obs.	107,934	107,934	107,934
R-squared	0.085	0.095	0.078
Controls	Yes	Yes	Yes
Health at birth	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes
Year-by-month FE	Yes	Yes	Yes

The dependent variables are the number of days spent in inpatient care at the age of 1-2 years. Respiratory diseases = ICD-10 codes J00-J99. Infectious diseases = ICD-10 codes A00-B99. Controls: sex of the child, the highest level of education, labor market status, occupation code, ethnicity, and age of the mother and father, marital status of the mother, number of previous live births, induced abortions, and spontaneous fetal losses of the mother. Control variables for health at birth: birth weight, gestation length, low APGAR score, SGA. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A12: Estimated change in health at birth when PHQI is improved (in SD units)

	Birth weight	LBW	SGA	Gestation length	PTB	Low APGAR
Mean of outcome	3327.3	0.0575	0.0978	38.85	0.0653	0.0522
SD of outcome	541.4	0.2328	0.2970	1.71	0.2470	0.2223
Coefficient	−24.39	0.0064	0.0140	−0.0106	0.0018	0.0011
Change when PHQI is improved by						
6	0.27	−0.16	−0.28	0.04	−0.04	−0.03
5	0.23	−0.14	−0.24	0.03	−0.04	−0.02
4	0.18	−0.11	−0.19	0.02	−0.03	−0.02
3	0.14	−0.08	−0.14	0.02	−0.02	−0.01
2	0.09	−0.05	−0.09	0.01	−0.01	−0.01
1	0.05	−0.03	−0.05	0.01	−0.01	0.00

Notes: Change is measured in units of SD of outcome. The coefficients are from Table 2.

Table A13: Estimated change in early childhood health when PHQI is improved (in SD units)

	Any diseases	Respiratory diseases	Infectious diseases
Mean of outcome	1.90	0.90	0.59
SD of outcome	7.39	4.21	3.27
Coefficient	0.108	0.067	0.034
Change when PHQI is improved by			
6	−0.09	−0.10	−0.06
5	−0.07	−0.08	−0.05
4	−0.06	−0.06	−0.04
3	−0.04	−0.05	−0.03
2	−0.03	−0.03	−0.02
1	−0.01	−0.02	−0.01

Notes: Change is measured in units of SD of outcome. The coefficients are from Table 3.