Effect of energy-efficient homes on residents' health: evidence from a natural experiment in the Netherlands

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Summary

Background Many governments around the world subsidise upgrades to poorly insulated homes, yet the extent to which these energy-efficiency improvements reduce health risks remains unclear. We aimed to provide the first large-scale evidence on whether such retrofits lower the use of respiratory health-care services, particularly for children and other vulnerable individuals.

Methods We leveraged a large-scale natural experiment in which public housing units across the Netherlands were retrofitted between 2012 and 2021. Upgrades included insulation and mechanical ventilation and were implemented in homes eligible on the basis of poor energy efficiency and construction before the early 1990s. Treatment assignment was based on technical factors and was therefore shown to be unrelated to health outcomes, and opting out was not possible. We followed up 2 million individuals over 10 years, totalling approximately 12 million person-years—a sample size that provided high statistical power (95% CIs narrow enough to detect relative risk changes in medication use as small as 1%). Individual-level medication data were obtained from health insurers. Medication use and other health-care outcomes among 180 000 tenants in retrofitted homes were compared with those in not-yet-retrofitted homes using a staggered difference-in-differences design with individual fixed effects. The primary outcomes were the use of prescription respiratory-system medications: asthma or chronic obstructive pulmonary disease drugs, cough remedies, and antihistamines.

Findings Antihistamine use declined by 1·87% (95% CI 0·19–3·55; p=0·029) after retrofits. Among children younger than 18 years, respiratory medication use fell by 3·76% (1·04–6·48; p=0·0067). Specifically, after 5 years, asthma medication use was reduced by 6·91% (–0·04 to 13·85; p=0·051). No statistically significant effects were found for non-respiratory medication outcomes and health-care costs.

Interpretation Energy-efficiency upgrades led to measurable reductions in respiratory medication use, especially for children. These benefits probably reflect reduced exposure to indoor dampness and bad air quality. Childhood asthma reduction is a crucial co-benefit of energy-efficiency home upgrades.

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Introduction

Housing is a key determinant of health.[1–3] Worldwide, many high-income countries have enacted programmes to upgrade insulation and ventilation in older housing.[4–6] An important question is how large the co-benefits of these energy-efficiency programmes are in reducing health risks and health-care use, in particular for children and other vulnerable individuals.

Existing empirical evidence on the effects of energy-efficient housing upgrades on health is scarce. Much of the literature comes from small experiments relying on self-reported health outcomes, and is therefore subject to measurement reactivity and recall biases.[7–9] The insights are mixed: although some studies found positive health effects, in particular for children or older people,[10] others did not document improvements in health scores, symptoms, or health-care use.

A large insulation and ventilation retrofit programme performed on Dutch public housing during 2012–21 offered a natural experiment for a large-scale impact evaluation. In 2012, a covenant required public housing providers to retrofit their older, poorly insulated dwellings. Over 1 million homes (half of the national public housing stock) were eligible; however, due to logistic constraints, only a share of these had been retrofitted by 2021. Treatment assignment was based on technical factors, uncorrelated to tenants' health. By law, tenants could not opt out, so comparable individuals received the upgrade at different times without choice, eliminating self-selection based on health. We evaluated the programme's health effects using objective health-care use measures (primarily individual medication use recorded by insurers), and distinguishing between vulnerable groups such as children, older people, and economically disadvantaged people.

Poor housing quality has been associated with numerous medical conditions, with the top four being respiratory

Research in context

Evidence before this study

We searched SCOPUS from database inception to July 30, 2025, for articles or reviews, in any language, containing the following terms: "health" AND ("retrofit" OR "insulation" OR "weatherization") AND ("house" OR "dwelling" OR "home"). We also considered the references in these studies. We found several studies on the health effects of home upgrades. Much of the literature comes from small-scale trials relying on self-reported outcomes. The insights are mixed: although some studies found positive effects, others did not document improvements in physical health scores or asthma symptoms. A large-scale German study found a reduction in hospital visits for older people after home upgrades. Large-scale causal evaluations are scarce and lack individual objective health measurements.

Added value of this study

Our large-scale analysis of the effects of energy-efficient home upgrades on medication use provides evidence that making homes more energy-efficient results in a reduction in respiratory medication use of children, suggesting a respiratory health improvement.

Implications of all the available evidence

Housing upgrades have environmental and health co-benefits, and particularly so for children and vulnerable groups. Future research should evaluate the long-term effects of home upgrades on children's health outcomes.

diseases, cardiovascular diseases, infections, and mental health.[1] Arthritis issues have also been reported.[11] These health outcomes can worsen due to cold homes and poor indoor air quality caused by inadequate insulation and ventilation.[12,13] The extent to which health outcomes are affected by upgrades differs by country, depending on climate and housing stock quality. The Netherlands has a mild climate with high humidity and the housing stock is equipped with adequate heating facilities. Consequently, respiratory conditions connected to indoor air quality probably have a major role in health outcomes.

Poor air quality, dampness, and mould in homes can exacerbate respiratory conditions, including asthma, especially for vulnerable groups who have weaker health or spend more time at home.[14,15] For example, older people have worse respiratory conditions than younger age groups. It is therefore plausible that a retrofit programme focused on improving thermal insulation and ventilation mitigates respiratory health hazards. Although the exact mechanisms are unclear due to the difficulty of measuring indoor climate (eg, humidity), potential mechanisms through which home improvements positively affect respiratory health are multifactorial. Insulation and ventilation improve indoor climate by reducing humidity, removing mould, and preventing mould growth, which are known triggers of respiratory conditions, especially asthma.[12] Better ventilation regulates air exchange and reduces occupant-generated indoor air pollutants and allergens associated with respiratory conditions (eg, dust mites and NO_2 from gas stoves and heaters).[16–18] In addition, lower energy use in well insulated homes saves around €200–400 per year,[6] and could indirectly improve health through higher household income.

The societal benefits of reducing respiratory illnesses are substantial. Asthma affects over 200 million people globally and accounts for half a million deaths annually.[19] For children, asthma is the most common chronic disease.[20] Home improvements are therefore expected to have larger effects on children, with greater lifetime benefits. Earlier research found that upgrades in housing conditions positively affected children's health and development when these conditions had been very poor (eg, in Bavaria in the 19th century and Mexico in the 20th century).[21,22] The present study examined whether energy-efficient upgrades provide important health benefits in a country where housing quality standards are already high from an international and historical perspective.

Methods

Intervention

Our intervention involved energy-efficient home upgrades performed in Dutch public housing in 2012–21. The retrofit programme, which started in 2012, targeted homes built before the early 1990s that had low energy performance certificates. Retrofits typically added or upgraded insulation in walls, floors, and ceilings, and installed mechanical ventilation to improve air exchange. Some projects also replaced windows. The aim was to raise the home's thermal quality above a minimum standard. These upgrades were effective; a companion paper documented reductions in energy demand for heating of around 20% after the upgrade. The upgrade intensity (ie, change in energy efficiency) differed per dwelling and was determined by dwelling characteristics. Energy savings due to retrofit ranged from 10% to 30%[6] and renovations were performed by the housing providers at negligible cost to tenants. The treatment effectively represented a targeted improvement in physical living conditions.

Study design

To evaluate the effect of home retrofits on the residents' health-care use, we leveraged an institutional feature of the retrofit programme that effectively turned it into a large-scale natural experiment. With over 1 million dwellings eligible, upgrades were phased in over multiple years, and only a relatively small proportion was upgraded by 2021. The decision of which homes to retrofit each year was based on technical factors (eg, building age and energy performance) and was uncorrelated with tenants' health, as supported by balancing tests. Opt-out was not possible by law.

We used data on 2 million residents over 10 years, amounting to approximately 12 million person-years, and compared individual outcomes before and after the home upgrades and between the treatment and the control groups. Homes that were upgraded by 2021 were assigned to the treatment group, whereas eligible homes that were not yet upgraded by 2021 were assigned to the control group. Eligible homes were built before 1993, built under construction standards that are not acceptable today, and had a European energy label between C and G, whereby label G stands for the least energy-efficient homes.

A key advantage of this natural experiment—encompassing 2 million individuals over a decade—is its high statistical power. This study allowed for the detection of even modest effects and detailed subgroup analyses, enhancing both precision and generalisability. Additionally, our natural experiment offered strong internal validity, often infeasible in large-scale studies, due to the unique institutional setting it took place in.

We used prescription medication data from mandatory insurance claims as a proxy for health outcomes. In the Netherlands, all residents are covered by compulsory health insurance, which includes prescription drugs reimbursed beyond an annual deductible of around €300. This study used individual-level records of reimbursed medications, including those below the deductible. We focused on respiratory drugs as they probably have the strongest response to home upgrades. Medication indicators, classified by the Anatomical Therapeutic Chemical (ATC) system to the fourth level, were available for each person-year. We also used annual individual-level reimbursed health-care costs, which cannot be linked to specific diseases.

Data used are de-identified administrative records. The study protocol was reviewed and approved by the Ethics Committee of Eindhoven University of Technology (approval number ERB2022BE20, May 12, 2022). All analyses were performed on secured servers and complied with data protection regulations.

Data sources

We linked at individual-address level three data sources: dwelling registry, health insurance claims, and population and socioeconomic registers. For dwelling registry, detailed information on all housing units (eg, building year, size, technical characteristics per year, and upgrade year if retrofitted) was provided by engineering bureau Atriensis and identifies when each home received a retrofit intervention. For health insurance claims, we used annual records of medication use covered by mandatory insurance. From these records, we constructed indicators of medication use (eg, asthma drug). These longitudinal individual data were provided by Statistics Netherlands. For population and socioeconomic registers, annual data on household composition, age, sex, household income, and other demographics were used to identify previously mentioned vulnerable groups. These data were provided by Statistics Netherlands.

	Dwellings	Individuals	Person-years
Original sample	1·15	3·16	28·40
Dwellings that qualify for retrofit	0·71	2·15	13·01
Qualifying dwellings not part of student or senior complexes	0·67	2·03	12·20

Dwellings and individuals are unique counts over the 2012–21 period, person-years are pooled over the study period.

Table 1: **Selection steps of treatment and control groups**

We first matched dwelling, health insurance, and population registers. The dwelling registry contains 1·15 million dwellings, which are matched to 3·24 million individuals over 10 years (only 260 dwellings could not be matched). Health insurance claims are matched to 3·16 million individuals (2·5% could not be matched), amounting to 28·40 million person-year observations.

We then selected treatment and control groups (table 1). First, we selected only dwellings that qualified for retrofit (ie, we excluded all dwellings built after 1993 and non-renovated dwellings with energy labels A or B). Second, we excluded student and senior housing complexes. This approach yielded an analysis dataset that included about 2 million individuals living in social housing, observed between 2012 and 2021. Our first treatment year was 2013 and our last was 2020; therefore, we had eight treatment-year cohorts. Observations were on a person-year basis (approximately 12 million person-years). On average, individuals were observed for 3·5 (SD 2) years after treatment in the same dwelling, providing substantial post-treatment follow-up. As we followed up on individuals over time, we have reported the size and respiratory medication outcome for each cohort (appendix pp 4–6).

See **Online** for appendix

Statistical analysis

Our analysis used a difference-in-differences approach and we used the fact that different homes were retrofitted in different years. We compared changes in outcomes in post-upgrade years relative to the pre-upgrade baseline, for treated versus control residents. This design controls for time-invariant differences between individuals (and housing complexes) and for calendar year effects. We estimated linear regression models of the form:

$$y_{i,j,t} = \beta \mathrm{Treated}_{j,t} + \delta_{i,j} + \phi_{a,t} + u_{i,j,t}$$

Here $y_{i,j,t}$ represents medication use and other health-care outcomes of individual i living in dwelling j in year t. The age a of the individual in a specific year is defined by i and t. The binary variable $\text{Treated}_{j,t}$ takes value 1 in the years following the retrofit and value 0 before; $\delta_{i,j}$ are individual-house fixed effects; $\phi_{a,t}$ are year fixed effects interacted with tenant's age fixed effects and $u_{i,j,t}$ is the idiosyncratic error term. The key coefficient β captures the average treatment effect on the treated population. For presentation purposes, we report $-\beta$, which can be interpreted as the absolute risk reduction (ARR).

We first estimated the ARR in respiratory medication use after retrofit, defined as the difference in pre–post changes between the treatment and control groups. We then derived the relative risk reduction (RRR) and its confidence interval, by dividing the ARR estimate by the baseline risk of medication use in the pre-retrofit year. The RRR is our main estimate and represents a percentage reduction in medication use, associated with the retrofit.

To compare individuals in the same home before and after the upgrade, we included individual-house fixed effects (estimations using separate individual and house fixed effects yielded similar results). To model age-specific time trends, year-by-age fixed effects were included to address violations of the underlying parallel trends assumption that would otherwise arise, since health outcomes evolve convexly with age. Our main approach, a difference-in-differences estimator, accounted for the bias introduced by staggered treatment timing (appendix p 3).[23–25] Standard errors were clustered at the housing complex level, where home upgrades occur. We used R version 4.4.3 for data processing and the package fixest 0.12.1 for analysis, which efficiently handles the millions of fixed effects in our regression model and removes singletons (eg, individuals appearing only in 1 year in our data).

To assess the validity of the parallel trends assumption and to examine the timing of effects, we estimated risk reduction coefficients by year relative to treatment. The year preceding the retrofit served as the reference period. Pre-treatment coefficients permitted visual inspection of whether treated and control groups exhibited parallel trends before upgrades, and post-treatment coefficients traced the evolution of effects over time. The ARR and RRR are aggregates of post-treatment coefficients, which are shown in difference-in-differences plots.

We focused on several respiratory outcomes: use of any respiratory-system medication (ATC code R), asthma or chronic obstructive pulmonary disease (COPD) medication (ATC code R03), antihistamines medication (ATC code R06; respiratory allergies), and cough and cold preparations (ATC code R05). We also considered cardiovascular (ATC code C) and arthritis (ATC code M01) medications, as well as health-care expenditures such as the general practitioner (GP), pharmacy, and hospital costs.

We conducted subgroup analyses for vulnerable populations: children (younger than 18 years), older people (older than 65 years), low-income households (household income below 130% of the social minimum income), and vulnerable people combined (children, older people, and low-income people).

We performed a number of sensitivity analyses to evaluate the results' robustness: time-varying covariates; using a conventional two-way fixed effects estimator; selecting children who used respiratory medication at least once during our period of observation; considering apartment and single-family dwellings separately; estimating short-run and long-run effects separately; estimating placebo effects (ie, considering health-care

	Treatment	Control
Respiratory medication (individual level), n	187 173	1 050 673
Respiratory medication, mean (n)	0·25 (46 299)	0·25 (260 031)
Asthma or COPD, mean (n)	0·12 (22 623)	0·12 (126 092)
Cough and cold preparations, mean (n)	0·04 (8228)	0·04 (44 808)
Antihistamines, mean (n)	0·08 (15 580)	0·09 (89 888)
Demographic factors (individual level), n	187 173	1 050 673
Children (younger than 18 years), mean (n)	0·21 (38 413)	0·18 (192 733)
Older people (older than 65 years), mean (n)	0·19 (35 369)	0·18 (193 391)
Female, mean (n)	0·52 (97 865)	0·52 (549 916)
Male, mean (n)	0·48 (89 308)	0·48 (500 757)
Socioeconomic factors (household level), n	89 400	536 924
Household income non-missing, mean (n)	0·94 (83 773)	0·94 (504 857)
Household yearly disposable income (€1000), mean (SD)	24·38 (11·50)	23·92 (14·57)
Low-income household, mean (n/N)	0·26 (21 174/80 265)	0·27 (128 637/479 758)

Statistics for the year 2012, of households and individuals in dwellings to be treated between 2013 and 2020 (treatment) and untreated dwellings as of 2021 (control). COPD=chronic obstructive pulmonary disease.

Table 2: **Balance between treatment and control groups at baseline**

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outcomes unlikely to be affected by retrofit, such as dental costs or GP administrative costs); and using data from before the natural experiment (ie, renovations before 2012).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Data for respiratory medication use and socio-demographics in year 2012, before any renovations started, for households and individuals living in dwellings to be treated between 2013 and 2020, and untreated dwellings as of 2021 are presented in table 2. Treatment and control groups were well balanced on observable characteristics before retrofit. The appendix (p 5) shows that the treatment and control group had parallel pre-treatment trends for each cohort.

For the difference-in-differences estimates for the full population and vulnerable groups, we controlled for individual-house fixed effects and allowed for age-specific time trends to eliminate possible confounders (table 3). Most of our estimates point to a risk reduction. In the full population, the RRR of antihistamine use was 1·87% (95% CI 0·19–3·55; p=0·029; ARR=0·0016). Among children, the RRR of respiratory medication was 3·76% (1·04–6·48; p=0·0067; ARR=0·0069).This reduction was mainly due to a 4·72% (0·64–8·79; p=0·023; ARR=0·0042) RRR in asthma or COPD medication use and a 3·75% (–0·57 to 8·08; p=0·089; ARR=0·0030) RRR in antihistamine medication use. We interpreted the reduction in asthma or COPD medication as a reduction in asthma medication use, as COPD medication use was negligible among children. For older people, we found no significant effect on respiratory medication use. For low-income households, the reduction in respiratory and antihistamine medication use was not convincingly supported by difference-in-differences plots (appendix pp 7–11).

Retrofit was associated with a 3·76% reduction in respiratory medication use among children. This association is shown with difference-in-differences plots (figure; appendix pp 7–11). These findings support the parallel trends assumption and suggest that the effect on asthma medication increases over time. We estimated short-run (1–4 years) and long-run effects (≥5 years; appendix pp 12–13). In the long run, the effect for children was larger: respiratory medication use fell by 5·51% (95% CI 0·94–10·09; p=0·018; ARR=0·0100), partly due to an asthma medication use reduction of 6·91% (–0·04 to 13·85; p=0·051; ARR=0·0061).

	Baseline	ARR	RRR (95% CI)	p value
Whole sample				
Respiratory medication	0·2482	0·0012	0·47% (–0·39 to 1·32)	0·28
Asthma or COPD	0·1202	–0·0004	–0·31% (–1·49 to 0·86)	0·60
Antihistamines	0·0850	0·0016	1·87% (0·19 to 3·55)	0·029
Cough and cold preparation	0·0447	0·0002	0·36% (–2·68 to 3·39)	0·82
Children (younger than 18 years)				
Respiratory medication	0·1822	0·0069	3·76% (1·04 to 6·48)	0·0067
Asthma or COPD	0·0886	0·0042	4·72% (0·64 to 8·79)	0·023
Antihistamines	0·0797	0·0030	3·75% (–0·57 to 8·08)	0·089
Cough and cold preparations	0·0079	0·0005	5·86% (–8·44 to 20·15)	0·42
Older people (older than 65 years)				
Respiratory medication	0·3124	0·0017	0·54% (–0·91 to 2·00)	0·47
Asthma or COPD	0·1904	–0·0001	–0·04% (–1·76 to 1·69)	0·97
Antihistamines	0·0641	0·0002	0·32% (–3·76 to 4·39)	0·88
Cough and cold preparations	0·0714	0·0025	3·52% (–1·20 to 8·23)	0·14
Low income (income below 130% social minimum)				
Respiratory medication	0·2852	0·0057	1·99% (0·19 to 3·78)	0·030
Asthma or COPD	0·1488	0·0020	1·35% (–0·98 to 3·68)	0·26
Antihistamines	0·0967	0·0043	4·47% (1·05 to 7·89)	0·010
Cough and cold preparations	0·0528	0·0020	3·88% (–1·92 to 9·69)	0·19
Vulnerable individuals (children, older people, and low-income people)				
Respiratory medication	0·2589	0·0035	1·34% (0·15 to 2·53)	0·028
Asthma or COPD	0·1406	0·0015	1·09% (–0·46 to 2·65)	0·17
Antihistamines	0·0806	0·0020	2·48% (0·09 to 4·88)	0·042
Cough and cold preparations	0·0444	0·0018	4·14% (0·03 to 8·25)	0·048

Shows estimates of the equation for 20 separate regressions. Baseline is the sample mean at baseline (ie, year before treatment). Sample sizes are reported in number (millions) of individual-year observations (number of individuals at the year of treatment; number of individuals in control homes across 2012–21): panel A 11·811 (0·177; 1·502); panel B 2·217 (0·037; 0·337); panel C 2·410 (0·036; 0·317); panel D 2·601 (0·040; 0·420); panel E 5·851 (0·091; 0·834). RRR represents a percentage reduction in medication use, associated with the retrofit. ARR=absolute risk reduction. COPD=chronic obstructive pulmonary disease. RRR=relative risk reduction.

Table 3: **Effects of home upgrade on respiratory medication**

Our result was confirmed by sensitivity analyses. First, it was robust when including time-varying controls (appendix p 14). Second, the conventional two-way fixed effects estimator yielded similar results (appendix pp 15–16). Third, we selected children that used respiratory medication at least once during our observation period. In percentage terms, we found identical reductions in respiratory medication (appendix p 17). Fourth, we analysed the effects separately for apartment and single-family dwellings, which accounted for 36% (apartment) and 64% (single-family) of our sample. We found a similar respiratory medication RRR among children in both subsamples, but the effect for single-family dwellings is only significant at the 10% level (appendix pp 18–19). Fifth, we did not find any significant effects on outcomes unlikely to be affected (placebo tests), such as dental costs and other expenditures, which supports our results (appendix p 20). Finally, using data from before the natural experiment (ie, renovations before 2012), we also found that children's asthma medication use declined over time, even though this treatment group does not overlap with the one examined in the main analysis (appendix pp 21–22).

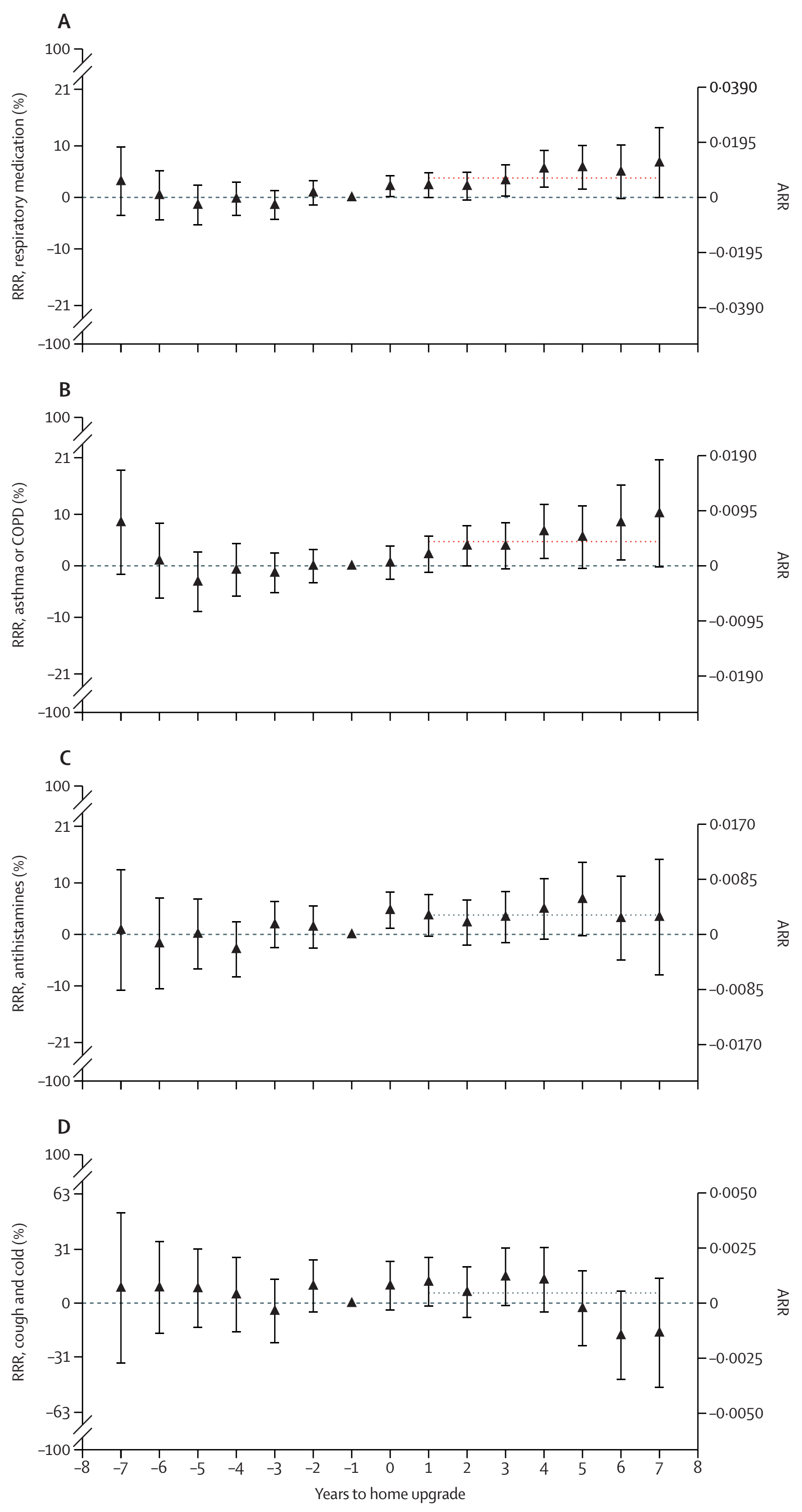

***Figure:* Effects of home upgrade on respiratory medication**

Difference-in-differences plots from four separate regressions. The bars represent the 95% CI. The left axis percentage change is relative to the sample average of the dependent variable in the year before home upgrade. Standard errors are clustered at housing complex level. Dotted horizontal lines represent the average treatment effect (red dotted lines indicate a statistically significant effect at a 5% level). Note that scales on y axes differ between plots. ARR=absolute risk reduction. COPD=chronic obstructive pulmonary disease. RRR=relative risk reduction.

Due to the specifics of the climate and housing stock in the Netherlands, we expected respiratory medication use to be reduced. We also expected children to have the largest effects among population groups. For completeness, we tested for effects on two other medication types (cardiovascular and arthritis; appendix p 23) and on health-care expenditure such as GP, pharmacy, and hospital costs (appendix p 24). The estimated effects were small and not statistically significant.

Discussion

In this large-scale natural experiment, upgrading the insulation and ventilation of older public housing in the Netherlands led to a measurable reduction in children's respiratory health-care use. In particular, children living in retrofitted homes used less asthma and allergy medication than comparable children whose homes had not yet been upgraded. The effect size—about a 4% decline in respiratory medication use—is modest but meaningful from a public health perspective.

These findings are consistent with the hypothesis that better-insulated, well ventilated homes reduce causes of respiratory conditions, dampness and mould, NO_2, and dust mites in the air. This result is in line with various smaller housing-intervention trials. For example, a randomised study in New Zealand found that insulating homes led to fewer self-reported childhood asthma attacks and better general health in children.[7] Our findings differ from a large-scale study in east Germany, which found an improvement of cardiovascular system outcomes in older people.[10] By contrast, we did not see any beneficial effect in this population (appendix pp 23–24). This difference might reflect differences in climate and quality of housing stock before treatment (more than 50% of east Germany houses did not have central heating or warm water systems before treatment).[10]

From a policy perspective, our evidence informs recommendations aimed at reducing the health burden for children in low-income households.[3] Upgrading public housing is not only an effective way to reduce energy expenditures for low-income households but also to improve health equity. Low income is typically associated with greater exposure to health hazards, especially among children. Our results show that these risks can be substantially mitigated through better insulation and ventilation.

The estimated health benefits could substantially alter the cost–benefit calculus of retrofitting programmes.[26] Asthma reduction alone is valued at €6400–29 000 per year,[27–29] suggesting that even a small reduction per child yields a sizable societal gain. This gain would translate to an estimated benefit of €40–180 per year per child living in retrofitted housing, based on our long-run childhood asthma estimate (appendix p 13). Given an annual discount factor of 5%, these benefits represent between 10% and 40% of the estimated retrofit costs.[6] Housing upgrades are key public health interventions.

Our analysis has strengths and limitations. The natural experiment—exploiting staggered roll-out and regulatory assignment—provides a credible estimate of causal impact. Using insurer records avoids recall bias and measurement reactivity bias. The large sample yields precision for subgroup analysis. Selection bias is unlikely: tenants could not self-select into upgrades, balancing tests showed that treated and control groups were highly similar in demographics and medication use, and difference-in-differences plots consistently supported the parallel trends assumption. However, we only observed the use of prescriptions; some milder symptoms treated without medication or unrecorded over-the-counter drugs were not captured. We also did not have direct measures of indoor conditions (eg, temperature and humidity) to link to outcomes, although those mediators are well documented in some smaller studies. Furthermore, our sample was restricted to social housing residents. Although the public housing sector in the Netherlands is large (30% of the housing stock) and houses people with different incomes (the household income test is only done once, when people move into the social housing), the results might not generalise to households outside public housing.

In conclusion, this study provides evidence that making homes more energy-efficient reduces respiratory medication use in children, suggesting improvements in their respiratory health. Given the long-term consequences of childhood asthma, these benefits could accrue over a lifetime. Policy makers should therefore consider health outcomes when designing and evaluating housing energy policies.

Contributors

VPR, IVO, and TAA developed the study concept. VPR and IVO collected and verified the data. VPR, IVO and JvO designed the study investigation. VPR did the data analysis. IVO accessed and verified the codes and routines. VPR wrote the first draft of the manuscript. All authors contributed to data interpretation and reviewed and edited the manuscript. All authors consented to submit the manuscript. VPR and IVO had access to all the data in the study.

Declaration of interests

We declare no competing interests.

Data sharing

The non-public microdata used in the paper are available via remote access to the Microdata services of Statistics Netherlands.

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