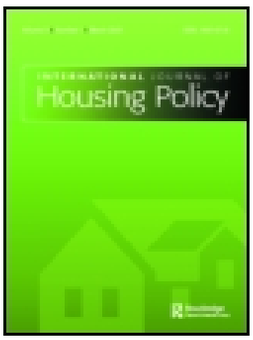

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Housing conditions and children's school results: evidence from Norwegian register data

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ABSTRACT

In this article, we investigate the extent to which housing conditions are associated with school results for children living in Norway. We link individual exam results of students from three national exams in the 5th, 8th and 10th grades for all children living in Norway in the years 2015–2017, to a number of official national datasets including a novel housing register that has information on key housing characteristics for all households in Norway. We also use a newly released noise register, which estimates noise exposure for every address in Norway. Our results show that living in a crowded home, in rented accommodation, being exposed to high levels of noise and residential mobility is associated with poorer exam results. This negative correlation is stronger for older children. However, further testing suggests that we can no longer rule out that the negative association between renting and overcrowding is driven by unobserved cofounders. Residential mobility and noise pollution, on the other hand, remain negative even after controlling for omitted variable bias.

KEYWORDS Housing; school results; noise pollution; neighbourhoods; residential mobility

INDEX-TERMS I21; R23; Q53; O18

Introduction

While most people in Norway live in safe, high-quality housing, this is not the case for everyone. Figures from Statistics Norway show that around four percent or 177,000 people live precariously in the Norwegian housing market, of which 65,000 are children (Thorsen, 2017).[1] Given the increasing evidence of the role of housing on educational outcomes (Leventhal & Newman, 2010; Umblijs et al., 2019), this can have potentially serious consequences. In turn,

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education is one of the most important predictors of later labour market success (OECD, 2019) making it high on the political agenda.

This paper looks at five important aspects of housing that the literature has identified as being associated with educational outcomes among children and young people, namely: overcrowding, home ownership, noise pollution, residential mobility and neighbourhood characteristics. We utilise individual level data that covers all Norwegian schoolchildren and their families in the period 2015 to 2017. The outcomes studied are the results of national exams in the 5th, 8th and 10th grades.

An important contribution of the article is the use of actual school exam records and official register information on housing, as well as individual and neighbourhood characteristics, thereby avoiding common problems such as sample selection, response bias or generalisability that accompanies research based on survey results. The register data also allows us to control for important household level characteristics. The household's socio-economic background, usually measured by parents' education and income, has been shown to be closely linked to both school results and housing conditions (Blau et al., 2015). Family size is also a possible factor here. Several studies find that children who grow up in large families do worse at school than children who grow up in small families (Black et al., 2005). At the same time, family size is an important determinant of the choice of home.

Our detailed data make it possible to test a number of associations between housing and educational performance. We evaluate the robustness to omitted variable bias using Oster's method (Oster, 2019). Furthermore, our measure of noise uses a novel methodology for estimating traffic, rail and flight noise for all addresses in Norway (Engelien et al., 2018). We are the first to use this register to study the relationship between noise pollution and education.

The rest of the paper is organised as follows. We start by presenting results from existing literature on the association between housing and educational outcomes, followed by a brief description of the educational system and housing market in Norway. We then present the data, sample and variables, while the next section explains the empirical specification. The last two sections are a presentation of the results and conclusion.

Previous literature

We focus on five aspects of housing conditions in this paper: overcrowding, homeownership, noise exposure, residential mobility and neighbourhood characteristics. In this section, we provide a brief outline of the literature looking at the link between these housing characteristics and education.

Previous research has shown that living in overcrowded conditions is negatively associated with educational attainment, as well as high school and university enrolment rates (Blau et al., 2015; Goux & Maurin, 2005; Lien et al., 2008; Solari & Mare, 2012). When simultaneously investigating parental home ownership, type of dwelling, and overcrowding, Bourassa et al. (2016) find that only overcrowding has a statistically significant correlation with educational attainment of children. Furthermore, there is evidence of a more pronounced negative overcrowding effect for older children (Lopoo & London, 2016). There is also evidence that the negative effects of overcrowding are persistent. Lopoo and London (2016) find that living in a crowded home during high school can lead to negative effects on university graduation rates at the age of 25.

Studies have found a link between homeownership and a wide range of outcomes for children (Dietz & Haurin, 2003). These outcomes include a reduction in teenage pregnancy rates (Green et al., 2012; Green & White, 1997), positive behaviour among children from low-to-moderate-income households in urban neighbourhoods (Grinstein-Weiss et al., 2012), positive effects on cognitive development (Haurin et al., 2002) as well as positive effects on educational credentials (Aaronson, 2000; Boehm & Schlottmann, 1999; Chen, 2013; Galster et al., 2007; Green et al., 2012; Green & White, 1997). There is also evidence that home ownership leads to higher levels of savings and consumption (Sodini et al., 2016), which in turn may affect children's education.

More recent literature reviews have not found a clear consensus on the topic of homeownership and children's outcomes, with some newer studies not finding a statistically significant relationship (Newman & Holupka, 2013). Harkness and Newman (2003) find that the homeownership variable is only significant for wealthier families. In a similar vein, Holupka and Newman (2012) find that after controlling for selection, the relationship between homeownership and children's cognitive achievement loses its statistical significance. Barker (2013) also highlights the difficulty of separating other factors such as building type and quality and unobserved parental characteristics from home ownership.

Other research suggest that residential stability either explains a significant amount (Galster et al., 2007), or all of the positive relationships between home ownership and educational attainment (Li, 2016; Mohanty & Raut, 2009). For example, Barker and Miller (2009) find that controlling for residential stability, as well as other housing characteristics, reduces or eliminates the positive effects of homeownership for children. A recent study by Aarland and Reid (2019) finds that home ownership had a substantial, positive impact on residential stability in Norway.

While these studies consider residential stability as an aspect of homeownership, others have focused on the stand-alone causal mechanisms of residential stability on children's outcomes. Research has suggested that

children exposed to higher levels of family instability show worse adjustments across a variety of development domains (Adam, 2004). Studies from psychology show that residential mobility in childhood can have a negative impact on self-reported well-being, health, self-esteem, ability to form friendships, and can increase the risk of substance abuse (Bures, 2003; Oishi & Talhelm, 2012; Oishi & Schimmack, 2010). All of these outcomes can in turn affect performance at school. There is still however some debate about the causal effect of residential stability. For example, Gasper et al. (2010) conclude that the link between residential mobility and children's behavioural outcomes (delinquency) is spurious and that there is selection in terms of the characteristics of families that move more frequently.

There is a growing literature that points to the harmful effect of noise. Results from both laboratory (Basner et al., 2014) and qualitative studies based on medical records (Sorensen et al., 2011) indicate that noise exposure can lead to increased irritation, sleep disturbance and a higher likelihood of stroke. Looking at educational outcomes, Stansfeld et al. (2005) find that attending a school with high traffic and aircraft noise is associated with weaker reading skills and memory among 9–10 year olds in the Netherlands, UK and Spain. Hygge et al. (2002) use the relocation of Munich Airport in Germany as a natural experiment to investigate the link between aircraft noise and cognitive performance of children and find a significant negative relationship.

Neighbourhoods can also play an important role in children's education. Existing research has found that better neighbourhoods are, among other things, associated with lower dropout rates from high school, reduced probability of having to repeat school years and better exam results (Crowder, 2001; Galster et al., 2016; Goux & Maurin, 2007; Harding, 2003). The positive effects of networks seem to be particularly important for immigrant children (Åslund et al., 2011) and the benefits of good neighbourhoods are stronger if a child begins experiencing them at a younger age (Chetty et al., 2016; Galster & Santiago, 2017). Furthermore, living in a neighbourhood with high crime and unemployment rates can cause children to feel unsafe and demotivated (Katz et al., 2001). This can interfere with the learning process and lead to poor learning outcomes. In a meta-analysis, Nieuwenhuis and Hooimeijer (2016) identify school, family socio-economic status (SES), and parent characteristics as important neighbourhood characteristics.

There is mounting evidence of a significant effect of neighbourhood characteristics on educational outcomes. While isolating neighbourhood effects are challenging, studies have utilised a number of innovative approaches to come closer to a causal interpretation. These include quasi-experimental designs (Casciano & Massey, 2012; Jargowsky & El Komi, 2011) looking at sibling effects (Aaronson, 1998) simultaneous estimation techniques (Carlson & Cowen, 2015), instrumental variable and matching methods (Galster

et al., 2016; Harding, 2003) as well as utilising variation in timing and duration of events (Sharkey & Sampson, 2010; Sharkey et al., 2012, 2014; Wodtke et al., 2011). These studies find a statistically significant relationship between neighbourhoods and various educational outcomes. Research utilising data spanning several decades also finds a negative effect of neighbourhood socioeconomic distress on high school drop-out rates (Crowder & South, 2003).

The methods used in the more recent literature advance the field considerably but they often have limitations. For example some articles utilise an instrumental variable approach where some form of housing characteristic such as house price indices (Galster et al., 2007; Holupka & Newman, 2012) or average homeownership rates (Aaronson, 2000; Chen, 2013; Holupka & Newman, 2012) are averaged by certain subgroups and used as an instrument. A potential weakness of this approach is that the instruments could affect children's outcomes through channels other than home ownership, breaking a central assumption of the approach. Another study (Goux & Maurin, 2005) utilizes gender composition of siblings as a part of an Instrumental Variable (IV) methodology. The IV methodology uses a variable (in this case gender composition of siblings) that induces changes in the explanatory variable (overcrowding) but has no independent effect on the dependent variable (education outcomes), allowing a researcher to uncover the causal effect of the explanatory variable on the dependent variable. Here however it is assumed that birth order and gender composition of siblings does not affect educational outcomes in ways not related to overcrowding, something which has been questioned by other literature (Bonesrønning & Massih, 2011). Natural experiments often provide a strong opportunity to tackle the problem of selection [see e.g., Galster et al. (2016); Galster and Santiago (2017)]. This method allows for comparison with a counterfactual group. However, by definition, this approach is restricted to the specific contexts where natural experiments can be applied.

There is a fast expanding literature on the effects of the five housing and environmental characteristics studied in this paper, namely overcrowding, home ownership, noise pollution, residential mobility and neighbourhood characteristics. When looking at these factors a key challenge is to identify and isolate the effect of interest. That neighbourhoods affect education is perhaps the most clearly established effect from the five characteristics. There is also strong evidence that residential mobility, renting and overcrowding is negatively associated with educational outcomes, although there are questions regarding the extent to which these characteristics can be isolated and effectively measured. There are fewer studies on noise pollution and educational outcomes, but the few existing studies point to a significantly detrimental effect of noise on school outcomes.

We contribute to the existing literature by using a detailed and comprehensive register based dataset covering all households in Norway. We

conduct an analysis of omitted variables based on Oster (2019) to test for potential selection effects of our housing variables. We also are the first to use a household based noise pollution database that includes all Norwegian dwellings to study educational performance.

Institutional framework

Compulsory education in Norway consists of seven years of primary school (grades 1–7, ages 6–12) and three years of lower secondary school (grades 8–11, ages 13–16). Norway practices very strict school enrolment rules, based on year of birth and place of residence. Primary and lower secondary school pupils have the right to attend the school that is closest to where they live or the school designated for the catchment area where they live. There is no ability tracking, and grade retention is very rare. As a result, almost all students follow grade by year of birth and attend the school where they live. The share of students attending private schools is very low. Private schools are heavily subsidised, and they follow the same curriculum as public schools. Exams and grading systems are uniform across the country. During compulsory school (5th, 8th and 9th grade), students undertake national-level, mandatory exams ('Nasjonale prøver') in reading, mathematics and English language. The purpose of these national exams is to give the schools knowledge of the students' basic skills, and the results have no consequences for the student taking the exams.

After compulsory school, students are entitled to three years of upper secondary education. Attending upper secondary school is voluntary; however, nearly all students (95%) have a direct transition from lower to upper secondary school. Students may choose between an academic-oriented track (three available programmes), and a vocational track (nine available programmes), which provides occupational certification. Admission into the different tracks and programmes is based on the grade point average (GPA) score, which consists of ten different grades from both exams and grades awarded from classwork ('standpunktkarakter'). GPA is measured at the end of compulsory school (10th grade).

The Norwegian housing market is characterised by a high share of homeowners (over 80%). Homeownership is a clearly stated policy goal, and is subsidised through generous debt deduction and low taxation. Individuals letting out privately owned homes dominate the rental market, and renting is predominantly of a temporary nature. However, high house prices and restricted access to financial markets make it difficult for households with variable incomes and little capital to enter homeownership. Some groups seem to be overrepresented among long-term tenants, such as those with low education and immigrants. Long-term tenants also tend

to have access to poorer housing and have higher living costs compared to short-term tenants and homeowners (Medby & Astrup, 2011). Households with very few financial resources may be eligible for public rental housing. This however is not very widespread, with public rented housing constituting only around four percent of the total housing stock, restricting eligibility to the most disadvantaged groups.

Our study contributes to the literature in a number of ways. We utilise a neighbourhood fixed effects approach that controls for important neighbourhood level characteristics when looking at our housing characteristics of interest. Although we do not have access to credible instrumental variables or natural experiments, we conduct an analysis of omitted variables based on Oster (2019) to test for potential selection effects of our housing variables.

Data, sample and variables

The starting point for our analyses is a new housing register compiled by Statistics Norway. This administrative register contains information on a number of housing characteristics linked to all individuals living in Norway, and covers the three years 2015, 2016 and 2017. We use anonymised individual ID numbers to link this data to other registers from Statistics Norway on employment and social security benefits for both parents and children, as well as demographic variables such as immigrant background, place of residence and age. For information on school results, we link the register data with the Norwegian National Education Database (NUDB).

One novel aspect of our analysis is the use of a national-level noise pollution dataset developed by Statistics Norway. This noise register provides information on noise exposure from all road, flight and rail traffic in Norway. For each source of noise, Statistics Norway has developed its own model for calculating exposure based on data about traffic flows, flight and train journeys (Engelien et al., 2018). It uses all these sources of information to estimate the amount of noise that reaches every address in Norway measured in average decibels per day.[2] We link this dataset to the household and individual registers.

The sample in our study is all students in the 5th, 8th and 10th grades in Norway between 2015 and 2017, that is, when students are 10, 13 and 16 years old. This includes nine full cohorts, or around 540,000 individuals. The key independent housing variables are crowdedness, tenure type and noise pollution. Information about crowdedness and tenure type is obtained from the housing register. We follow the definition provided by Statistics Norway, and define an overcrowded household as one where 1) the total number of rooms is lower than the number of persons residing in

the home and 2) there is less than 25 square meters of floor space per person. The housing register also contains information on whether the household owns or rents their home.[3]

Hazardous noise exposure is defined along WHO guidelines as noise levels exceeding a daily average of 55 decibels (WHO, 2018). To capture residential mobility we include a dummy variable for having moved neighbourhoods at least once in the three years prior to taking the exams.[4] We also include a broad range of neighbourhood characteristics: the proportion of neighbourhood residents who are non-western immigrants, university graduates, receive disability benefits, or social assistance, as well as average income in the neighbourhood. All neighbourhood variables are measured at the level of 'grunnkrets', the smallest administrative geographic unit in Norway, with an average 884 adult residents.

The educational outcomes we look at in this study are results of national school exams in the 5th and 8th grades, as well as the grade point average (GPA) score in the 10th grade. National tests in the 5th and 8th grades are mandatory nationwide tests that map skills in reading, mathematics and English (as a foreign language). The results are measured in standardised scale points (standardised with average 50 and standard deviation 10), and in our analysis we use the average score across all subjects. The GPA score from the 10th grade is standardised in the same way as the other tests to make the results comparable.[5] Table 1 shows descriptive statistics of our sample of students.

Empirical specification

The purpose of this paper is to investigate the relationship between our housing variables and school results for the three national exams. We start by investigating the association between housing and exam results without controlling for other factors. All housing variables are included simultaneously. As a next step, we include a number of household and individual characteristics. We conduct our analysis using neighbourhood characteristics both as control variables and within a neighbourhood fixed effects approach. The latter compares outcomes for children and young adults living within the same neighbourhood, thus taking into account time-invariant differences in school quality and other unobserved factors at the neighbourhood level.

Our main specification is as follows

$$y_{it} = \alpha + \beta x_{it} + \varepsilon_{it}, \ i = 1, \ldots .N, \ t = 2015, \ldots, \ 2017$$

Where y_{it} represents the exam results for one of the three national exams (at 5th, 8th and 10th grade) for students that took that test in the years 2015, 2016 and 2017. The explanatory variables, x_{it}, are divided into four

Table 1. Descriptive statistics.

	Mean	Min.	Max.	Std.	N
Housing characteristics					
Overcrowded	0.16	0	1	0.37	525,549
Rented home	0.11	0	1	0.31	540,000
Noise pollution	0.42	0	1	0.49	518,030
Residential mobility	0.14	0	1	0.34	540,000
Neighbourhood characteristics					
Share immigrants	6.85	0	83.33	8.96	538,098
Share with university education	32.80	0	100	13.31	538,097
Share receiving disability benefits	7.67	0	100	3.62	538,098
Share receiving social assistance	2.74	0	71.43	2.26	538,098
Log median income	12.94	1.70	13.75	0.15	538,095
Centrality	0.13	0	1	0.33	538,098
Individual characteristics					
Female	0.49	0	1	0.50	540,000
Immigrant background	0.09	0	1	0.29	540,000
Household characteristics					
At least one parent with university education	0.56	0	1	0.50	540,000
Household receiving disability benefits	0.07	0	1	0.26	540,000
Household receiving social assistance	0.04	0	1	0.20	535,893
Household size	4.24	1	17	1.18	535,893
Number of children in household	2.14	0	12	0.98	535,893
Income quartile 1	0.18	0	1	0.38	535,893
Income quartile 2	0.28	0	1	0.45	535,893
Income quartile 3	0.31	0	1	0.46	535,893
Income quartile 4	0.24	0	1	0.43	535,893
School results					
National test 5th grade	50	23.96	72.64	10	179,012
National test 8th grade	50	24.48	73.28	10	176,754
GPA 10th grade	50	3.16	72.38	10	184,235

Students 10, 13 and 16 years old in the period 2015–2017.

categories. First, we include housing characteristics: crowdedness, home ownership, noise pollution, residential mobility, and neighbourhood characteristics (share of immigrants, university educated, disability benefit recipients, social assistance recipients, as well as neighbourhood median income). Secondly, we include individual characteristics (gender and immigrant background) and household characteristics (an indicator variable for at least one parent being university educated, the household receiving disability benefits, household size, number of children in household and the combined income quartile of parents). We also control for the year of the exam. Finally, we include a specification where we substitute the neighbourhood characteristics with dummies for each neighbourhood; a neighbourhood fixed effect approach. All standard errors are clustered at the neighbourhood level.

Our reliance on OLS and fixed effects estimates means that our results cannot be directly interpreted causally. We do however include a wide range of control variables to ensure that important aspects of the home and neighbourhood environment are not driving the results. Furthermore, by comparing the relationship between housing and schooling for various

age groups we can see how the relationship between the home environment and schooling changes as the children get older. Lastly, we investigate the sensitivity to omitted variable bias by employing the method generalised by Oster (2019), and provide upper and lower bounds for the impact of the different housing condition variables on school results.

Results

National school exam results for 5th graders

In Table 2, we present results for the OLS and fixed effects estimations for 5th grade exam results.[6] The first column shows results from a specification including only the housing and neighbourhood characteristics and year dummies. The second column includes individual and household effects, while the third column replaces the neighbourhood characteristics with neighbourhood fixed effects. The coefficients can be interpreted as a change in exam results in scale points when the housing variable is changed by one unit. For example, in Column 1, we see that living in a crowded home is associated with a 1.6 scale point reduction in national 5th grade school exam results. As expected, there is a negative association between school results and the housing characteristics. Interestingly, both the rented home and the residential mobility coefficients are negative and statistically significant. This suggests that while having moved home at least once in recent years is associated negatively with school results, this relationship does not account for the negative association between renting and school outcomes.

The results in Column 1 also suggest that neighbourhood characteristics play a significant role. Our results show that living in a neighbourhood with a higher proportion of university graduates, a higher proportion of immigrants and higher median income is associated with better school results. On the other hand, living in a neighbourhood with a high proportion of individuals on disability benefits and social assistance recipients, as well as living in a central neighbourhood, is negatively correlated with school outcomes.

In Column 2, we control for household, individual and neighbourhood characteristics. The results show that all of the housing variables, apart from 'the proportion of disabled individuals in the neighbourhood', remain statistically significant. On the other hand, the size of most of the housing coefficients is reduced by more than a half from Column 1 to Column 2. The magnitude of most of the neighbourhood variables is also reduced. While the noise variable in the OLS specification is positive, we suspect it might be correlated with other neighbourhood characteristics and we are therefore most confident about the neighbourhood fixed effects results when

Table 2. 5th grade national exam results, OLS and fixed effects.

	(1) OLS	(2) OLS	(3) FE
Housing characteristics			
Overcrowded	−1.644***	−0.483***	−0.563***
	(0.0702)	(0.0729)	(0.0773)
Rented home	−3.213***	−1.087***	−1.142***
	(0.0944)	(0.0974)	(0.105)
Noise pollution	−0.107	0.110*	−0.113
	(0.0561)	(0.0542)	(0.0595)
Residential mobility	−1.392***	−0.703***	−0.690***
	(0.0774)	(0.0758)	(0.0805)
Neighbourhood characteristics			
Share immigrants	0.0265***	0.0517***	
	(0.00465)	(0.00480)	
Share with university education	0.127***	0.0714***	
	(0.00347)	(0.00343)	
Share receiving disability benefits	−0.0269*	−0.00824	
	(0.0120)	(0.0116)	
Share receiving social assistance	−0.0646***	−0.0620***	
	(0.0191)	(0.0178)	
Log median income	1.736***	0.809*	
	(0.363)	(0.338)	
Centrality	−0.419***	−0.498***	
	(0.0953)	(0.0927)	
Individual and household characteristics	No	Yes	Yes
Year dummies	Yes	Yes	Yes
Neighbourhood fixed effects	No	No	Yes
Constant	24.74***	35.53***	48.45***
	(4.703)	(4.374)	(0.148)
Observations	167,304	167,304	167,306
R^2	0.069	0.119	0.214

Notes. Students 10 years old in the period 2015–2017. Standard errors in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
Standard errors are clustered at the neighbourhood level. Individual characteristics include gender and immigrant background. Household characteristics include indicator variables for at least one parent being university educated and the household receiving disability benefits, household receiving social assistance, household size, number of children in household and the combined income quartile of parents.

looking at noise (Column 3). Not surprisingly, household and neighbourhood characteristics are important for school results.

We compare these results with those using a neighbourhood fixed effects specification in Column 3. Here we only compare children and

young people living in the same neighbourhood, thus eliminating the effect that the neighbourhood may have on schooling. The results from the fixed effects estimations indicate that the neighbourhood variables that we have included in Column 2 cover important aspects of the neighbourhood regarding young people's educational outcomes. However, one coefficient that is different between the two models is 'noise pollution', which is now again negative. This suggests that variation in noise levels within a neighbourhood play an important role for school results. Since high noise levels for the vast majority of our sample originate from road traffic, distance to major roads for students could be an important consideration.

Most of the housing variables in the FE regression in Column 3 are statistically significant. However, they are rather small in magnitude. As the mean of the national exams is 50 with a standard deviation of 10, the estimate of −0.6 for overcrowding corresponds to a reduction of 0.06 standard deviations or 1.2 percent measured from the mean. In comparison, having at least one parent with university education is associated with an increase in scale points in the size of 0.38 standard deviations or 7.6 percent (Table A1 in the Appendix). While it is difficult to compare the magnitudes across countries the coefficients we find in Norway do appear to be somewhat lower than in other countries. For example, Lopoo and London (2016) find that a 1 standard deviation increase in crowding is associated with a 2.2 percentage point decline in the likelihood of graduating from high school in the US. In Taiwan, children having their own bedroom increases the probability of starting high school by 1% (Lien et al., 2008). These larger coefficients could potentially be due to greater diversity in housing characteristics in these countries or the more egalitarian schooling policies in Norway.

National school exam results for 8th graders

Results for national tests in the 8th grade are shown in Table 3. All coefficients of the housing variables in Column 1 are negative and statistically significant. As with 5th grade exam results, the fixed effects models yield relatively similar results compared to the OLS specification that control for neighbourhood effects (comparing Column 3 with Column 2). It is worth noting that for both national tests, the relationship between the proportion of non-Western immigrants in the neighbourhood and school outcomes is positive (Tables 2 and 3, Columns 1 and 2). This finding goes somewhat against the preconception that schools in areas with a large proportion of immigrants face more challenges and therefore perform worse than neighbourhoods with fewer immigrant children. It should be noted here that this positive correlation is found after controlling for other neighbourhood

Table 3. 8th grade national exam results, OLS and fixed effects.

	(1) OLS	(2) OLS	(3) FE
Housing characteristics			
Overcrowded	–2.066***	–0.679***	–0.821***
	(0.0729)	(0.0739)	(0.0788)
Rented home	–3.977***	–1.472***	–1.520***
	(0.0914)	(0.0920)	(0.100)
Noise pollution	–0.267***	–0.0118	–0.146*
	(0.0537)	(0.0518)	(0.0584)
Residential mobility	–1.813***	–1.044***	–1.042***
	(0.0811)	(0.0776)	(0.0840)
Neighbourhood characteristics			
Share immigrants	0.0222***	0.0633***	
	(0.00412)	(0.00432)	
Share with university education	0.159***	0.0951***	
	(0.00344)	(0.00337)	
Share receiving disability benefits	–0.0324**	–0.0190	
	(0.0111)	(0.0107)	
Share receiving social assistance	–0.0651***	–0.0718***	
	(0.0171)	(0.0163)	
Log median income	1.490***	0.631	
	(0.360)	(0.323)	
Centrality	–0.625***	–0.690***	
	(0.0884)	(0.0848)	
Individual and household characteristics	No	Yes	Yes
Year dummies	Yes	Yes	Yes
Neighbourhood fixed effects	No	No	Yes
Constant	27.56***	37.15***	48.37***
	(4.652)	(4.181)	(0.139)
Observations	165819	165819	165819
R^2	0.093	0.160	0.244

Notes. Students 13 years old in the period 2015–2017. Standard errors in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
Standard errors are clustered at the neighbourhood level. Individual characteristics include gender and immigrant background. Household characteristics include indicator variables for at least one parent being university educated and the household receiving disability benefits, household receiving social assistance, household size, number of children in household and the combined income quartile of parents.

characteristics. Comparing the results across the 5th and 8th grade, we also see that all housing coefficients are larger for exam results in the 8th grade compared to the 5th grade.

Similar to 5th grade results residential mobility is negatively associated with school results in all three specifications. The magnitude of this effect is

relatively large but the rented home variable is also significant and negative with residential stability included, suggesting that other aspects related to tenure are important.

National school exam results for 10th graders

When looking at GPA results for 10th graders, we find much of the same pattern. The four housing characteristics variables are significantly negatively correlated with exam results. However, the magnitude of all of them is larger for the 10th grade compared with the other two exams. For example, residential mobility is negatively associated with results in 10th grade, but coefficients are significantly larger, being around double the magnitude compared with 5th and 8th grade exams. This finding corresponds to results from previous studies [see e.g., Lopoo and London (2016) and Bourassa et al. (2016)], which find that the relationship between housing and educational outcomes is stronger for older children. In Norway the purpose of the 5th and 8th grade exams is primarily to provide a basis for quality assessment of the teaching, and children are not required to prepare for the exams. On the other hand, 10th grade GPA results play a decisive role in further education choices. The students therefore have stronger incentives to work hard over a longer period for good results for the 10th grade GPA, making the role of the home environment increasingly more important.

A further difference between the 10th grade results and the other two exams is the association between the number of non-Western immigrants in the neighbourhood and school results. Without controlling for individual and household characteristics, there is a negative association between the share of immigrants in the neighbourhood and educational attainment. This association is not significant when we control for individual and household characteristics (Table 4, Column 2). Another difference is the association between neighbourhood income and school results, which turns negative when controlling for individual and household characteristics. An explanation for this could be due to the result of redistributive funding policy of some municipalities, including Oslo, which essentially result in more deprived areas receiving more funding. This could in theory lead to more disadvantages students living in poorer areas receiving more support in school than disadvantaged students who live in more deprived neighbourhoods. This is an interesting topic for further research.

Selection on unobservables

Our reliance on OLS- and FE-models makes it difficult to know whether selection or causation is driving the relationship between housing

Table 4. 10th grade GPA national exam results, OLS and fixed effects.

	(1) OLS	(2) OLS	(3) FE
Housing characteristics			
Overcrowded	−1.938***	−1.105***	−1.077***
	(0.0774)	(0.0749)	(0.0805)
Rented home	−5.371***	−2.068***	−2.078***
	(0.0972)	(0.0941)	(0.101)
Noise pollution	−0.616***	−0.323***	−0.404***
	(0.0533)	(0.0478)	(0.0557)
Residential mobility	−3.371***	−2.202***	−2.256***
	(0.0835)	(0.0759)	(0.0822)
Neighbourhood characteristics			
Share immigrants	−0.0243***	0.00736	
	(0.00479)	(0.00490)	
Share with university education	0.117***	0.0452***	
	(0.00309)	(0.00290)	
Share receiving disability benefits	−0.0586***	−0.0278**	
	(0.0107)	(0.00964)	
Share receiving social assistance	−0.0698***	−0.0702***	
	(0.0171)	(0.0151)	
Log median income	0.677*	−0.604*	
	(0.322)	(0.303)	
Centrality	−0.303***	−0.325***	
	(0.0879)	(0.0769)	
Individual and household characteristics	No	Yes	Yes
Year dummies	Yes	Yes	Yes
Neighbourhood fixed effects	No	No	Yes
Constant	39.58***	49.56***	42.93***
	(4.162)	(3.916)	(0.123)
Observations	173,085	173,085	173,086
R^2	0.103	0.270	0.340

Notes. Students 16 years old in the period 2015–2017. Standard errors in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
Standard errors are clustered at the neighbourhood level. Individual characteristics include gender and immigrant background. Household characteristics include indicator variables for at least one parent being university educated and the household receiving disability benefits, household receiving social assistance, household size, number of children in household and the combined income quartile of parents.

characteristics and school results. To assess the importance of omitted variable bias, we apply the procedure developed by Oster (2019). This method uses information about coefficient stability and changes in R-squared when adding covariates to estimate the bias arising from selection on unobservables. More specifically, the method allows us to estimate a bias-adjusted

Table 5. 5th grade national exam results.

	(1) Baseline effect (std.error)		(2) Controlled effect (std.error)		(3) Bias-adjusted β $R_{max} = 1.3R^2$	(4) δ for β = 0 given R_{max}
Overcrowded	−2.478	(0.074)	−0.483	(0.072)	0.480	0.527
Rented home	−4.277	(0.089)	−1.087	(0.097)	0.656	0.653
Noise pollution	−0.011	(0.063)	0.110	(0.054)	0.151	−2.845
Residential mobility	−2.158	(0.077)	−0.703	(0.075)	−0.144	1.248
Share immigrants	−0.029	(0.004)	0.051	(0.004)	0.105	−1.448
Share university educated	0.144	(0.002)	0.071	(0.003)	−0.043	0.742
Share receiving disability benefits	−0.399	(0.011)	−0.008	(0.011)	0.302	0.032
Share receiving social assistance	−0.425	(0.020)	−0.062	(0.017)	0.200	0.279
Log median income	10.58	(0.553)	0.809	(0.338)	−13.710	0.080
Centrality	0.557	(0.113)	−0.498	(0.092)	−0.833	−1.522

Notes. Students 10 years old in the period 2015–2017. Test of selection on unobservables using Oster (2019). R_{max} is defined as the R-squared from a hypothetical regression of the outcome on the full set of observed and unobserved variables. As recommended by Oster, $R_{max} = 1.3*R^2$ from the controlled regression. δ characterises the proportional degree of selection, and is set to 1 in Column (3).

treatment effect, under the assumption that selection on observed and unobserved variables is proportional. In addition, the method provides an estimate of the degree of selection on unobservables relative to observables necessary to produce a treatment effect of zero.[7]

Tables 5–7 show the results from the Oster-procedure, estimating the impact of the housing and neighbourhood variables on school results. We start out by estimating the model using only covariates that are unrelated to the selection process, here defined as sex and cohort fixed effects. This is our baseline model, presented in Column 1. As a next step, we estimate the model using the full set of controls (Column 2 in Tables 2–4). This is our controlled regression, using Oster's terms, and the results are shown in Column 2 of Tables 5–7.

Critical for the Oster-procedure is the value of R_{max}, defined as the R^2 from a hypothetical regression of the outcome on the full set of observed and unobserved variables. R_{max} is set by the researcher, and Oster recommends a value of R_{max} equal to 1.3 times the value of R^2 from the controlled regression. In addition, we need to set a value on δ, the parameter characterising the proportional degree of selection. A value of δ equal to 1 means that the unobservable variables are equally important in explaining the outcome as the observed variables.

The bias-adjusted estimates arising from the Oster-procedure with $R_{max} = 1.3*R^2$ and δ = 1 are shown in the third row of Tables 5–7. These estimates may be interpreted as upper bounds on the treatment effect, with the estimates from the controlled regression as lower bounds. The last

Table 6. 8th grade national exam results.

	(1) Baseline effect (std.error)		(2) Controlled effect (std.error)		(3) Bias-adjusted β $R_{max} = 1.3R^2$	(4) δ for β = 0 given R_{max}
Overcrowded	−3.178	(0.079)	−0.679	(0.073)	0.502	0.601
Rented home	−5.223	(0.090)	−1.472	(0.092)	0.562	0.749
Noise pollution	−0.183	(0.064)	−0.012	(0.051)	0.038	0.243
Residential mobility	−2.928	(0.082)	−1.044	(0.077)	−0.362	1.503
Share immigrants	−0.044	(0.004)	0.063	(0.004)	0.129	−1.395
Share university educated	0.173	(0.002)	0.095	(0.003)	−0.031	0.847
Share receiving disability benefits	−0.463	(0.011)	−0.019	(0.010)	0.322	0.067
Share receiving social assistance	−0.510	(0.017)	−0.072	(0.016)	0.223	0.284
Log median income	12.31	(0.674)	0.631	(0.323)	−15.99	0.054
Centrality	0.696	(0.117)	−0.690	(0.084)	−1.122	−1.627

Notes. Students 13 years old in the period 2015–2017. Test of selection on unobservables using Oster (2019). See Table 5.

Table 7. 10th grade GPA national exam results.

	(1) Baseline effect (std.error)		(2) Controlled effect (std.error)		(3) Bias-adjusted β $R_{max} = 1.3R^2$	(4) δ for β = 0 given R_{max}
Overcrowded	−3.702	(0.084)	−1.105	(0.075)	0.613	0.676
Rented home	−7.078	(0.088)	−2.068	(0.094)	1.934	0.560
Noise pollution	−0.912	(0.063)	−0.323	(0.048)	−0.076	1.298
Residential mobility	−5.113	(0.081)	−2.202	(0.076)	−0.615	1.352
Share immigrants	−0.103	(0.004)	0.007	(0.005)	0.106	−0.099
Share uni. educated	0.131	(0.002)	0.045	(0.003)	−0.109	0.427
Share receiving disability benefits	−0.378	(0.009)	−0.028	(0.010)	0.391	0.092
Share receiving social assistance	−0.589	(0.019)	−0.070	(0.015)	0.418	0.180
Log median income	11.11	(0.669)	−0.604	(0.303)	−26.57	−0.040
Centrality	0.743	(0.122)	−0.325	(0.077)	−0.772	−0.754

Notes. Students 16 years old in the period 2015–2017. Test of selection on unobservables using Oster (2019). See Table 5.

columns show the degree of selection on unobservables relative to observables (δ) that would be necessary to wipe out the effect of the housing variable altogether. A value of $\delta = 1$ means that the unobservables are equally important as the observables to produce a zero effect. Oster suggests that results with a $\delta > 1$ can be viewed as robust, that is, results in which the unobservables are more important in explaining away the treatment than the observed controls.

The results in Tables 5–7 show that two of our housing variables – noise pollution and residential mobility – in most cases survive the Oster-procedure. Overcrowding and rented home, on the other hand, do not exclude

zero in the identified set for the lower and upper bound. We can therefore not rule out that unobserved confounders drive the negative associations between these variables and school results. As for the neighbourhood characteristics the results vary with the outcome studied. The immigrant share and centrality survive the Oster-procedure for the national exams in the 5th and 8th grade, but not for 10th grade GPA.

Conclusions

In this article, we use a novel dataset that includes registry-based information on a number of important aspects of housing for all residential dwellings in Norway. By linking this data with a household specific noise pollution register, we obtain a detailed picture of the living conditions of Norwegians between 2015 and 2017. We also use small geographic identification units together with income and social security register datasets to control for neighbourhood characteristics. We use this information to see how the home environment is associated with school results for all students in 5th, 8th and 10th grades, when the children are 10, 13 and 16 years old respectively.

Our results confirm that the home and neighbourhood environment plays an important role for school results. The majority of our housing variables are significantly associated with school exam results. Living in a crowded home and being exposed to high levels of noise are associated with poorer exam results. Living in a household that owns its own home and residential stability is on the other hand associated with better exam results. We find that these relationships become weaker, but in most cases remain significant, after we control for individual and household characteristics. However, after controlling for selection on unobservables using the method of Oster (2019), we can no longer rule out an insignificant association between homeownership and overcrowding, and children's school results. Residential mobility and noise pollution, on the other hand, remain negative even after testing for omitted variable bias.

Another main finding is that housing and neighbourhood characteristics seem to play a more important role for older students. This corresponds to previous research, which has also found a higher significance of the home environment for adolescents compared to younger children. One reason for this may be that having a quiet and stable place to do homework is more important for older children (Lopoo & London, 2016). Another reason may be that GPA results play a more important role for further education choices and requires more continuous effort over a longer period of time, making the home environment more important.

The finding that neighbourhood characteristics play a more important role for older students stands in opposition to the findings from the neighbourhood effects literature, which find a more positive effect for younger children (Chetty et al., 2016; Galster & Santiago, 2017). This different result could be due to the fact that in the studies cited families are assigned housing and subsequently moved to neighbourhoods with different characteristics. Possibly the disruptive effect of moving is more detrimental to older compared to younger children, counteracting the positive neighbourhood effect.

Looking at the neighbourhood characteristics a clear result is that more university-educated individuals in the neighbourhood are correlated with better results. Some of our other findings motivate further research. For example, we find that for some age groups a higher share of immigrants and lower median neighbourhood income are associated with better school results. A possible explanation is the redistributive school policies in Norway that lead to schools in poorer neighbourhoods receiving more financial assistance. Further research could shed light on this hypothesis.

A main contribution of our study is the use of population-level information about noise measured at the dwelling to investigate the association between noise pollution and educational outcomes. Interestingly, the association between noise exposure and school results is strongest and most precisely measured in the fixed-effects specification, comparing students living in the same neighbourhood. This implies that variations in noise levels within neighbourhoods play an important role for school results, such as distance to major roads.

There are several shortcomings of our study. Firstly, we cannot interpret our results as causal. Despite access to detailed register data, we cannot rule out omitted variables bias, that is, left-out variables correlated with both our independent variables of interest as well as the outcome variable. However, the negative influence of residential mobility and noise pollution on exam results survives a robustness test for selection on unobservables, as developed by Oster (2019), suggesting that our results are not entirely driven by omitted variable bias. Another potential limitation concerns the measurement of noise pollution. The noise register contains estimated noise levels measured outside each dwelling in Norway. Ideally, we would have access to observed noise levels inside the dwelling, taking into account differences in insulation and building materials that may significantly affect the experienced noise level.

Nevertheless, this article highlights the importance of the home and neighbourhood environment for educational attainment. We contribute to the existing literature by using a detailed and comprehensive register based dataset covering all households in Norway. We also are the first to use a

household based noise pollution database that includes all Norwegian dwellings to study educational performance. Statistics Norway has only recently made the Norwegian housing data available to researchers and therefore the research currently covers only three years. There will be greater possibilities for further research using more rigorous methods when more years of data are made available, making it possible to follow students over time and compare their exam results as they progress through the school system.

Notes

1. Statistics Norway's operationalisation of a household living in a precarious living situation is defined as one that has low income (lower than 60% of the median income) in addition to living in an overcrowded home and/or having household debt that exceeds three times the total pre-tax yearly income. Overcrowding is defined as living in a home where the number of rooms is lower than the number of people in the household, in addition to the number of square meters being below 25 per person.
2. The latest update of the noise register is in 2014. The modelling of noise provides no information on how the noise level is experienced inside the home, which will depend, among other things, on how well the home is insulated.
3. As there is no consensus in the literature as to the definition of overcrowding, we have investigated the sensitivity of the results using different measures of overcrowding, varying the number of square meters of floor space per person. The less square meters per person, the more negative is the association between overcrowding and school performance. Results are available from the authors upon request.
4. Ideally, we would observe whether the individuals move homes, and not neighbourhoods. However, as our data do not contain such information other than for the years 2015–2017, we use neighbourhood as a proxy for residential mobility.
5. Although the national tests are mandatory, some children are exempted from participating, such as pupils receiving special education. There have also been claims that schools hold children away from the national-level mandatory exams in Norway in order to improve the school's reputation and ranking. Around five per cent of the children in our sample lack scores on the national tests, which is in line with official figures from the Norwegian Directorate of Education and Training. Descriptive statistics (available from the authors upon request) show that these children tend to live more precariously than those who participate in the national tests. By excluding these children from the analyses, we potentially underestimate the role of housing for the national exams.
6. Full estimation results are provided in the appendix.
7. The Oster-procedure does however not rule out selection on unobservables related to the treatment and not related to the observed controls

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability

Restrictions apply to the availability of the data used under license from Statistics Norway for this study. Data are available from the authors upon reasonable request and with permission of Statistics Norway only.

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Appendix

Table A1. Full estimation results.

	(1) 5th grade FE	(2) 8th grade FE	(3) 10th grade FE
Overcrowded	−0.563***	−0.821***	−1.077***
	(0.0773)	(0.0788)	(0.0805)
Rented home	−1.142***	−1.520***	−2.078***
	(0.105)	(0.100)	(0.101)
Noise pollution	−0.113	−0.146*	−0.404***
	(0.0595)	(0.0584)	(0.0557)
Residential mobility	−0.690***	−1.042***	−2.256***
	(0.0805)	(0.0840)	(0.0822)
Year 2016	−1.069***	−1.139***	0.410***
	(0.0695)	(0.0645)	(0.0553)
Year 2017	0.719***	−0.302***	0.644***
	(0.0685)	(0.0633)	(0.0565)
Female	−0.120*	0.317***	5.126***
	(0.0502)	(0.0499)	(0.0466)
Immigrant background	−1.278***	−2.360***	−0.724***
	(0.118)	(0.114)	(0.115)
At least one parent with uni. education	3.742***	4.351***	5.164***
	(0.0588)	(0.0558)	(0.0516)
Household receiving disability benefits	−1.296***	−0.920***	−1.147***
	(0.134)	(0.106)	(0.0826)
Household receiving social assistance	−2.354***	−2.668***	−3.063***
	(0.161)	(0.157)	(0.153)
Household size	−0.481***	−0.486***	−0.176***
	(0.0466)	(0.0393)	(0.0310)
Number of children in household	0.526***	0.630***	0.794***

(*continued*)

Table A1. Continued.

	(1) 5th grade FE	(2) 8th grade FE	(3) 10th grade FE
	(0.0580)	(0.0480)	(0.0375)
Income quartile 2	0.628***	0.609***	1.031***
	(0.0882)	(0.0883)	(0.0817)
Income quartile 3	1.356***	1.270***	2.305***
	(0.0933)	(0.0944)	(0.0845)
Income quartile 4	2.391***	2.364***	3.725***
	(0.103)	(0.101)	(0.0893)
Constant	48.45***	48.37***	42.93***
	(0.148)	(0.139)	(0.123)
Observations	167,306	165,819	173,086
R^2	0.214	0.244	0.340

Notes. Students in 5th, 8th and 10th grades (10, 13 and 16 years old) in the period 2015–2017. Neighborhood fixed effects. Standard errors in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.