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GERMS IN THE FAMILY:
THE SHORT- AND LONG-TERM CONSEQUENCES OF INTRA-HOUSEHOLD DISEASE SPREAD

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Germs in the Family: The Short- and Long-Term Consequences of Intra-Household Disease Spread

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ABSTRACT

Preschool-aged children get sick frequently and spread disease to other family members. Despite the universality of this experience, there is limited causal evidence on the magnitudes and consequences of these externalities, especially for infant siblings with developing immune systems and brains. We use Danish administrative data to document that, before age one, younger siblings have 2-3 times higher hospitalization rates for respiratory conditions than older siblings. We combine birth order and within-municipality variation in respiratory disease prevalence among young children, and find lasting differential impacts of early-life respiratory disease exposure on younger siblings' earnings, educational attainment, and mental health-related outcomes.

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1 Introduction

Children get sick frequently, especially when they are in group childcare settings at young ages, and during the fall and winter seasons when common viruses circulate. While regular exposure to infectious diseases is inevitable in our society and beneficial for training children's immune systems (Adda, 2016; Holt and Jones, 2000; Côté et al., 2010; Fink et al., 2021), preschoolers' sickness might exert important externalities within their families, especially on younger infant siblings who are in a vulnerable period of rapid brain development (Eppig et al., 2010; Bhalotra and Venkataramani, 2013). Yet despite the universality of this experience among families with young children, there is limited empirical evidence quantifying such within-family externalities.

This paper focuses on the spread of respiratory illnesses among young children and studies the magnitudes of these externalities over the short and long-run. We use population-level Danish administrative data covering 37 birth cohorts to study: (i) how respiratory illnesses spread from older to younger siblings during their first year of life, when they are particularly vulnerable to severe disease and complications, and (ii) how respiratory disease exposure during infancy affects the younger siblings' long-term economic, human capital, and health outcomes.

We begin by documenting a striking disparity in the likelihood of severe respiratory disease during infancy by birth order. Using data on all first- and second-born siblings born in Denmark between 1981 and 2017, we find that younger siblings have two to three times higher rates of hospitalization for respiratory conditions during their first year of life compared to the older siblings at the same age, and that this gap is particularly large when hospitalizations are measured in the first three months of life.[1] Moreover, the hospitalization disparity is larger if the younger sibling is born in the fall or winter, when respiratory viruses circulate more frequently. The hospitalization gap is also larger for siblings with shorter birth spacing, who may be more prone to close contact that facilitates virus transmission. These patterns highlight the family unit as being central in virus transmission, and the previously understudied mechanism by which birth order might influence children's longer-term outcomes—

[1]Note that this finding builds on several prior studies that document that higher-order siblings have *better* health outcomes at birth than first-borns (e.g., Brenøe and Molitor, 2018; Pruckner et al., 2021). Thus, it appears that younger siblings experience higher rates of severe respiratory infection, despite having better health at birth than their older counterparts.

older children "bring home" common viruses (e.g., from group childcare environments), putting their younger siblings at heightened risk of severe respiratory illness in the first few months of life.

Next, we demonstrate differences in age-30 earnings by birth order, season of birth, and birth spacing. Using cohorts born between 1981 and 1989—who can be observed through age 30 in our income data—we find that groups with higher respiratory disease incidence have lower adult earnings on average. Specifically, younger siblings born in fall or winter months and in families with short birth spacing have lower earnings than other groups. However, while this relationship is suggestive of a potential link between infancy respiratory illness and adult earnings, it is unlikely to reflect a purely causal relationship because of other ways in which birth order, season, and spacing influence later outcomes (e.g., Black et al., 2005; Buckles and Hungerman, 2013; Buckles and Kolka, 2014).

We therefore rely on a quasi-experimental approach to identify the long-term causal impacts of early-life respiratory disease exposure. Specifically, we combine the birth order variation in the likelihood of severe respiratory infection together with variation in local disease prevalence. Local respiratory disease prevalence among children is largely driven by highly infectious conditions, such as the Respiratory Syncytial Virus (RSV) and the influenza virus, which spread across locations in irregular seasonal waves (Pitzer et al., 2015; Adda, 2016).[2] We construct a municipality-level index, which is designed to capture respiratory disease exposure during each child's first year of life from slightly older children in the community. We calculate the number of hospitalizations for respiratory conditions per 100 children aged 13 to 71 months in each municipality, and then assign to each child the cumulative child hospitalization rate in their municipality over their first 12 months of life.[3] We then use our sample of siblings to estimate the differential effect of the disease index for younger compared to older siblings. Our regressions control for birth spacing, birth order, and municipality and birth-

[2] Pitzer et al. (2015) identifies climatic factors—including temperature, vapor pressure, precipitation, and potential evapotranspiration—as important predictors local infectious disease spread, while Adda (2016) shows the role of social and economic factors, such as public transportation and schools. While climatic, social, and economic factors may have impacts on long-term outcomes through channels unrelated to respiratory disease spread (see, e.g., Isen et al., 2017a, for evidence on early-life exposure to extreme temperature), we note that such channels are unlikely to differentially influence first versus second-born children.

[3] If a given child has an older sibling who is between 13 and 71 months of age during their first year of life, we exclude the older sibling from the hospitalization rate.

year-by-month fixed effects, thus accounting for other differences between older and younger siblings and the impacts of birth spacing, time-invariant differences across municipalities that might drive differences in disease exposure, and aggregate and seasonal trends in respiratory illness and long-term outcomes.

We show that the local respiratory disease index predicts the likelihood that a child is hospitalized for a respiratory illness during the first year of life, and that this impact is much larger for younger relative to older siblings. We find that moving from the 25th to the 75th percentile in the disease index distribution is associated with a 0.024 differential increase in the number of respiratory illness hospitalizations in the first year of life for younger relative to older children, representing an additional 34.2 percent increase at the sample mean. This effect is in part driven by a differential increase in hospitalizations for RSV, which is a mild illness in most older children but can be extremely serious among infants.[4]

In the long run, we observe that increased exposure to severe respiratory illness during infancy among second-born children has negative effects on their adult wage earnings and total income. We find that, for the younger siblings, moving from the 25th to the 75th percentile in the disease index distribution exposure in the first year of life leads to additional 0.8 and 0.9 percent reductions in wage earnings (conditional on employment) and overall income, respectively, at ages 25–32, compared to their older counterparts. We also find a 0.3 percentage point differential decline in the income percentile rank in the overall Danish population, which includes individuals with zero earnings. We do not find any significant impacts on the extensive margin of labor force participation.

The estimated interquartile effects on long-term earnings among younger siblings are comparable to the effects of a 10 percent reduction in birth weight (Black et al., 2007) or a 9 percent increase in ambient air pollution in one's year of birth (Isen et al., 2017b); they correspond to almost two-thirds of the impacts of *in utero* exposure to the 1918 Spanish Influenza pandemic (Almond, 2006) and one-fourth of the effect of *in utero* exposure to a maternal influenza infection that requires hospitalization (Schwandt, 2018). We further show that the effect of birth

[4]In most healthy individuals, RSV causes mild, cold-like symptoms. But in infants, RSV can cause severe respiratory infections, including bronchiolitis and pneumonia. Recent estimates suggest that approximately 14.7 per 1,000 infants under six months of age and 2.9 per 1,000 children under age five are hospitalized with RSV every year (Rha et al., 2020). For comparison, the highest COVID-19 hospitalization rate for children ages 0–4 (in January 2022, at the height of the Omicron wave) is estimated to be 0.16 per 1,000 (see: `https://gis.cdc.gov/grasp/covidnet/covid19_3.html`).

order on long-run earnings documented in prior seminal work (Black et al., 2005) is half as large when we control for the infancy disease environment, suggesting that intra-household disease transmission from older to younger siblings may be an important channel.

We explore several additional medium- and long-term outcomes to better understand the potential mechanisms behind the observed effect on adult earnings. We first examine impacts on hospitalizations for respiratory conditions in later childhood. We find that higher respiratory disease exposure before age one is associated with a *lower* likelihood of hospitalization for all respiratory conditions at ages three to four, consistent with an immunity formation hypothesis.[5] However, this protective effect disappears after age four, and we do not see any significant relationship between infancy respiratory disease exposure and hospitalizations for respiratory conditions at older ages. Thus, while the protective effects of infancy exposure to respiratory disease are limited to the first few years of childhood, there also does not appear to be any adverse impact on respiratory health in later childhood or young adulthood. Put differently, our estimated effects on adult earnings do not appear to be driven by a long-term deterioration in respiratory health.

We further analyze different measures of human capital accumulation available in the register data, finding some limited evidence of adverse effects. An interquartile increase in respiratory disease exposure during the first year of life is associated with a 0.01 of a standard deviation penalty in the ninth grade Danish test score among younger siblings. Point estimates for ninth grade mathematics test scores are similar but not statistically significant. We also find that younger siblings are 1.3 and 1.2 percentage points less likely to graduate high school by age 20 and college by age 25, respectively, although there is some indication of catch-up at older ages. These relatively small impacts suggest that a deterioration in educational outcomes is unlikely to be a central mechanism explaining the long-term earnings effects.

[5] At the same time, we do not observe a protective effect on the likelihood of subsequent hospitalization for RSV. This result is consistent with RSV being only a partially immunizing disease—that is, an RSV infection does not provide full immunity against future illness (Lambert et al., 2014; Fuentes et al., 2016). This lack of immunity formation, combined with the fact that RSV accounts for a large share of all respiratory hospitalizations during infancy (30 percent among second-born children), suggests that RSV might be a particularly important driver of the adverse long-term impacts on educational and economic outcomes. Unfortunately, we cannot measure the long-term effects of RSV illness directly, as RSV is not contained in the International Classification of Disease version 8 (ICD-8) coding system that was used in Denmark until 1994. Thus, we can only measure RSV exposure for cohorts born in 1994 and later, when Denmark switched to the ICD-10 system, and these cohorts are too young to measure adult outcomes through age 32 in our data.

Our analysis of later respiratory health and educational outcomes implies that there is likely another important channel through which infancy respiratory disease exposure influences adult earnings. The biomedical literature points to a link between respiratory illness, the impairment of brain development during infancy, and later development of mental health conditions (Adams-Chapman and Stoll, 2006; Bilbo and Schwarz, 2012; O'Shea et al., 2013). As summarized by Bhalotra and Venkataramani (2013), this literature emphasizes the importance of fast neural development coupled with a high degree of neural plasticity during the first few months of life. During this stage of human development, about 85 percent of calorie intake is used for neural growth (Eppig et al., 2010), and severe illness can both reduce calorie intake as well as divert calories away from brain development to fighting the disease. Deverman and Patterson (2012) argue that inflammatory responses to illness can also directly impair brain development.[6] These illness-driven disruptions of brain development are hypothesized to impair later-life mental health, which is an important input into human capital and economic productivity (see, e.g., Bütikofer et al., 2020; Biasi et al., 2021).

We shed light on potential mental health impacts by studying the utilization of mental health care with inpatient and outpatient encounters data. We find that moving from the 25th to the 75th percentile in the respiratory disease index distribution during the younger sibling's first year of life is associated with 0.56 additional visits (4.1 percent at the sample mean) to psychiatric hospital and private psychiatric clinics at ages 16–26, with the effect mostly concentrated in less severe cases that tend to be treated at private clinics. These mental health impacts are smaller in magnitude than existing estimates of the effects of more extreme fetal and early childhood shocks on later mental health outcomes, including exposure to Ramadan (Almond and Mazumder, 2011), maternal stress due to the death of a relative (Persson and Rossin-Slater, 2018), and changes in economic conditions (Adhvaryu et al., 2019).

Lastly, we analyze heterogeneous impacts on both respiratory hospitalizations during infancy and long-run outcomes along a variety of dimensions, including parental socio-economic status, the younger sibling's gender and health at birth, child birth spacing, and whether the older sibling is in a childcare center. When it comes to the short-run effects on respiratory

[6]Medical treatment occurring during hospitalization for severe respiratory illness has the potential to additionally harm brain development, e.g., when infants are put into medically induced coma to allow for prolonged ventilation (Vliegenthart et al., 2017).

hospitalizations, we find that the effects are disproportionately concentrated among low birth weight younger siblings (those with birth weight less than 2,500 grams). Further, younger male siblings experience a larger differential increase in respiratory hospitalizations than their female counterparts, which is consistent with the "fragile male" hypothesis (i.e., the idea that male fetuses and infants are biologically more vulnerable to various shocks and stressors, see, e.g. McCarthy, 2019; Sanders and Stoecker, 2015; Kraemer, 2000). The effect on hospitalizations also seems to be monotonically decreasing with birth spacing—that is, younger siblings in families with a shorter birth spacing gap have a larger differential increase in hospitalizations before age one. The estimated impact on respiratory hospitalizations is also larger in sibling pairs in which the older child is attending a childcare center compared to pairs in which the older child is not. These patterns further support the conjecture that intra-family spread is a key mechanism in driving higher rates of respiratory illness among younger siblings.[7] When it comes to heterogeneity in long-run impacts, we find that the adverse effects on adult income are larger among males than females, consistent with what we see for respiratory hospitalizations during the first year of life. Moreover, we find for both short- and long-term outcomes that effects are stronger for disease exposure during the first six months of life compared to the second half of the first year in line with the idea that infants are particularly vulnerable in the months right after birth.

This study contributes to an expansive body of work on the human capital impacts of early life circumstances (Barker, 1990; Currie and Almond, 2011; Black et al., 2017; Almond et al., 2018). This literature includes estimates of the impacts of a vast range of prenatal and early childhood factors—from economic resources (e.g., Hoynes et al., 2016; Adhvaryu et al., 2019; Bailey et al., 2020) to nutrition (e.g., Almond and Mazumder, 2011) to environmental conditions (e.g., Almond et al., 2009; Isen et al., 2017b; Black et al., 2019) to maternal stress (e.g., Black et al., 2016; Persson and Rossin-Slater, 2018). The literature on infectious diseases in early childhood has focused on severe infectious diseases, such as malaria, measles, and polio, that have been largely eliminated in high-income countries but still exist in the developing

[7]Further, the heterogeneous results by birth spacing suggest that our effects are *not* driven by differences in parental investments between older and younger siblings (and the potential interactions between these investments and our disease indices). Price (2008) finds that in the U.S., the difference in parent-child quality time between first- and second-born children is larger when the birth spacing gap is longer. Our pattern of a monotonically decreasing effect with birth order is the opposite of what would be predicted if differential parental time investment were the main channel.

world (Bleakley, 2010; Barreca, 2010; Cutler et al., 2010; Lucas, 2010; Venkataramani, 2012; Chang et al., 2014; Barofsky et al., 2015; Gensowski et al., 2019; Kuecken et al., 2021; Fink et al., 2021; Chuard et al., 2022), and on large-scale pandemics like the 1918 Spanish Flu (Almond, 2006; Almond and Mazumder, 2005; Lin and Liu, 2014) and the 1957 Asian Flu (Kelly, 2011).[8] Our study builds on this work by studying a range of respiratory illnesses that circulate among young children on a regular basis, and by focusing on the first year of life instead of the prenatal stage.[9] Our novel estimates of long-term impacts of severe respiratory disease can inform household behaviors and cost-benefit evaluations of policies designed to curb transmission of common viruses, including vaccination mandates, drug distribution programs, and sick pay regulations (Adda, 2016; Bhalotra and Venkataramani, 2015; White, 2019; Van den Berg and Siflinger, 2020; Pichler and Ziebarth, 2020; Bütikofer and Salvanes, 2020; Atwood, 2022; van den Berg et al., 2023).

Our analysis further contributes to the literature on birth order and sibling spillovers, which has documented worse human capital and life outcomes for later-born children relative to first-borns (Black et al., 2005; De Haan, 2010; Buckles and Kolka, 2014; Brenøe and Molitor, 2018; Lehmann et al., 2018; Breining et al., 2020; Black et al., 2021). This literature typically points to family resources and uneven parental investments as drivers of younger siblings' disadvantage (Price, 2008). Our results suggest that the disease environment during infancy is an additional source of disadvantage for later-born children, and that the older sibling likely serves as a vector of transmission. Importantly, the long-term effects we measure are net of any parental responses to the health shocks. To the extent that parents may respond to one child's sickness in a compensatory way—as found by Yi et al. (2015) and Daysal et al. (2020)—the sibling differences in long-run outcomes that we find represent lower bound estimates of the uncompensated (i.e., "biological") impacts of respiratory illness during infancy on later well-being.

[8] Schwandt (2018)'s analysis is an exception in that it focuses on the impacts of exposure to a common endemic respiratory virus—the seasonal influenza—but only during the *in utero* period.

[9] Studies in the medical literature have analyzed the health impacts of RSV infection, with a focus on asthma as an outcome. These studies use relatively small samples of children to correlate RSV infection (or RSV hospitalization) with later health conditions (e.g., Kneyber et al., 2000; Korppi et al., 2004; Kusel et al., 2007; Régnier and Huels, 2013; Zomer-Kooijker et al., 2014; Carbonell-Estrany et al., 2015). A recent study using Finish data analyzes the association between hospitalization for any infection at ages 0–18 and adult economic outcomes (Viinikainen et al., 2020). We are not aware of studies using quasi-experimental designs to isolate causal impacts of early life RSV exposure, or those using population-level administrative data.

2 Data and Sample

We use several population-level administrative data sets from Denmark in our analysis. These data include individual-level records with unique personal identifiers that allow us to follow individuals over time and to link family members to one another. Below, we describe the main variables used in our analysis and the data sources from which they are drawn.

Outcomes. Our key short-run outcome is the number of hospitalizations with a primary diagnosis of a respiratory condition during the first year of life. We measure this outcome using the *National Patient Register*, which is available to us for years 1981–2018 and includes all inpatient admissions to public and private hospitals, along with International Classification of Disease (ICD) diagnosis and procedure codes (Lynge et al., 2011). Denmark used the International Classification of Disease version 8 (ICD-8) coding system until 1994, and then switched to the ICD-10 system for all years going forward.

We classify inpatient visits with the following primary diagnosis codes as respiratory disease-related: ICD-8 codes starting with "46," "47," "48," "490," "079," and "783"; and ICD-10 codes starting with "B974" or "J" (excluding "J4"). In some analyses, we use data on cohorts born in 1994 and later and examine hospitalizations for RSV specifically, which we identify with ICD-10 codes J12.1 (respiratory syncytial virus pneumonia), J20.5 (acute bronchitis due to respiratory syncytial virus), J21.0 (acute bronchiolitis due to respiratory syncytial virus), and B97.4 (respiratory syncytial virus as the cause of diseases classified elsewhere).[10]

Our primary long-run outcomes are measures of adult labor force participation and income. We use the *Register-Based Labour Force Statistics* available for years 1980–2019 to characterize labor force participation. This dataset is based on tax records, and contains information on the labor market status of the entire Danish population as of November of the preceding year (Petersson et al., 2011). We construct an indicator equal to one if an individual is in the labor force and zero otherwise (i.e., those who are employed and unemployed but searching are both coded as 1; those out of the labor force are coded as 0). We use the *Income Statistics Register* for years 1980-2019 to construct measures of income, converted into 2010 $USD. Our

[10]We can only measure RSV from 1994 onward (when ICD-10 was used in Denmark) because the ICD-8 system did not have any codes specific to RSV.

first measure of income is wages among those who are employed. We also calculate gross personal income, including government transfers. We examine effects using both the level and the natural log of income measures. Finally, we create a variable that denotes the percentile rank of an individual's gross personal income in the overall Danish population (i.e., not just our analysis sample) in each birth cohort and at each observed age. We study these labor market outcomes at ages 18 through 32.

In order to shed light on potential mechanisms driving the long-run effects, we examine effects on educational outcomes, respiratory hospitalizations at older ages, and mental health care utilization. For human capital outcomes, we consider ninth grade Danish (reading) and mathematics test scores from the *Academic Achievement Register* (available for 2001–2019), and the highest level of completed schooling from the *Education Register* (available for 1981–2019). We standardize test scores within subject and test year such that they have a mean of zero and a standard deviation of one. We measure long-run educational outcomes with indicators for having graduated from high school and from college, respectively, measured by ages 18 through 32. To study effects on mental health care utilization, we use the *Psychiatric Central Research Register* and the *Health Insurance Register*. The former is a dataset containing all inpatient admissions, outpatient visits, and emergency department (ED) visits to psychiatric units in public and private hospitals. The latter dataset provides information on reimbursements to private practices—both general practitioners and specialists—for all health services covered by the national health insurance system. We measure visits to psychiatric hospitals and to private psychiatric clinics, using physicians' specialty codes ("24" or "26"), both at the extensive and intensive margins. These registers are available to us for years 1997–2018, and we examine mental health care utilization outcomes at ages 16 through 26.

Control variables. We observe a rich set of child and parent characteristics, using the previously described registers as well as the *Population Register* and the *Birth Register*. The *Population Register* provides a snapshot of demographics on all Danish residents as of January 1st of each year (Pedersen, 2011). The *Birth Register* includes the universe of births in Denmark, with information on the exact date of birth, gender, plurality, birth weight, and gestation length. It also has unique parental identifiers, allowing us to link siblings and

determine birth order.[11]

We include the following variables as controls, measured at the time of childbirth: child gender, birth weight, maternal age, maternal foreign-born status, maternal education level, and parental marital/cohabitation status.[12] We also include controls for the natural log of the mother's, father's, and the family's total income, as well as each parent's employment status, all measured in the year before childbirth. Lastly, we include the birth spacing between siblings in months, as well as an indicator for being the younger sibling interacted with birth spacing.

Finally, in some of our heterogeneity analyses, we make use of a data set containing information on children's enrollment in Danish childcare centers, which is reported annually in September of each year. This information is available to us over the period of September 1995 to September 2013.

Analysis sample. To construct our analysis sample, we begin with the universe of 2,278,868 children born between 1981 and 2017 in Denmark and make the following restrictions. First, we exclude families with only one child. Second, we only keep the first and second-born children in every family, and further, we only keep families in which the first and second-born children are singletons. Third, we only keep children in sibling pairs with a birth spacing gap of at least 11 months, which ensures that there is no overlap in the first year of life of the two children. Fourth, we only keep children with non-missing information on municipality of birth and who are born in municipalities that have an average of at least 1,000 children aged 13–71 months over the sample period, which ensures that we have sufficient observations to calculate the respiratory disease exposure index as described in Section 4 below.[13] Finally, we drop children with missing parental control variables, and keep sibling pairs in which both

[11]Specifically, the birth records contain identifiers for all mothers. If the mother is married at the time of childbirth, then her husband is automatically registered as the biological father. If the mother is unmarried, then the biological father's identifier is listed if he establishes paternity. Fathers' identifiers are missing for only 0.58% percent of observations in our analysis period.

[12]Information on parental marital/cohabitation status is collected from the year after birth, due to the lag in administrative record.

[13]Denmark changed its administrative municipality structure in 2007, which led to a reduction in the total number of municipalities from 275 to 98. We use the current municipality structure in our analysis, and use a crosswalk that matches each pre-2007 municipality to the appropriate municipality code used from 2007 onward. When dropping municipalities with an average of fewer than 1,000 children aged 13–71 months over the sample period, we drop 7 municipalities, such that our final analysis sample contains 91 municipalities in total.

children remain in the sample after these restrictions. Appendix Table A1 shows how our sample size evolves as we make these various restrictions to arrive at our final analysis sample.

Our final analysis sample consists of 1,230,180 children, which we use to analyze short-term impacts of respiratory disease exposure on hospitalizations in the first year of life. When studying long-term outcomes, we use children born in cohorts who can be observed in our outcome data at the ages at which outcomes are measured.

3 Descriptive Analysis Based on Differences By Birth Order, Season, and Spacing

3.1 Differences in Respiratory Disease Hospitalizations during Infancy

We begin with a descriptive analysis of respiratory disease hospitalization patterns among children in our sample, comparing first- and second-born siblings. This analysis sheds light on a likely mechanism through which respiratory diseases spread within families—older children, most of whom interact with same-age peers in group childcare settings and are therefore frequently exposed to infectious viruses, "bring home" diseases that infect their younger siblings.

Raw sibling differences. Panel (a) of Figure 1 plots the average number of respiratory disease hospitalizations (per 100 children) by child age in months during the first year of life. It shows that, compared to first-born children, younger siblings have two to three times higher rates of hospitalization for respiratory disease, and that the difference is especially large when children are two and three months of age. Panel (b) of Figure 1 extends the time horizon on the $x-$axis to 60 months (i.e., age five), and demonstrates that the difference in hospitalization rates between older and younger siblings disappears after age one. This pattern is consistent with the vast majority of Danish children staying home with their mothers during their first half year of life, and only starting to attend group childcare towards the end of the first year.[14]

[14]In Denmark, some form of maternity leave has been available since the beginning of the 20th century. In 1980, mothers had access to 14 weeks of nearly fully paid leave following the birth of a child, and this leave benefit was extended to 24 weeks (and also began to include fathers) in 1985 (Rasmussen, 2010). Subsequently, additional weeks of leave were added with reduced benefit compensation. By 2002, new parents could receive

Thus, after age one, younger and older siblings are similarly likely to be exposed to infectious viruses in group care environments, whereas non-first-borns have exposure before they turn one through their older siblings bringing viruses home.[15]

Seasonal differences. In Figure 2, we explore the role of respiratory disease seasonality in driving the observed hospitalization gap between siblings. The two graphs in Figure 2 show the average number of respiratory disease hospitalizations for older and younger siblings, respectively, separately by season of birth. These graphs reveal three facts. First, children are more likely to be hospitalized for respiratory disease during the winter when common respiratory disease outbreaks (such as RSV) are more prevalent—children born in November, December, and January have the highest hospitalization rates in the first three months of life; those born in August, September, and October have the highest hospitalization rates at 3 to 6 months old; those born in May, June, and July have the highest hospitalization rates at 7 to 9 months old; and those born in February, March, and April have the highest hospitalization rates at 10 to 12 months old. Second, younger siblings have higher hospitalization rates than older siblings regardless of season of birth. Third, out of all sub-groups considered, younger siblings born in the winter months have the highest hospitalization rates when they are two to three months old, suggesting that they are particularly susceptible to severe respiratory infections during early infancy.

Birth spacing differences. In Figure 3, we examine differences in these patterns across siblings with different birth spacing gaps. Each graph plots the average number of respiratory disease hospitalizations per 100 children by age in months of the older siblings (on the left) and the younger siblings (on the right), separately by season of birth and for different birth spacing gaps. The graphs demonstrate that younger siblings born in winter months have the highest hospitalization rates regardless of birth spacing, and that the difference in hospitalizations between younger and older siblings gets much smaller as birth spacing increases. This pattern

up to 52 weeks of parental leave with partial pay. The majority of this leave is used by mothers (see, e.g., Beuchert et al., 2016).

[15] Appendix Figure A1 plots the share of children enrolled in a group childcare center, nursery, or preschool by age in months. Virtually no children attend childcare before they turn one year old, and the share increases rapidly over ages one to two. There is a small jump at age three, when children are eligible to attend formal preschool centers (as opposed to less formal nurseries for younger children). More than three-quarters of children are enrolled in a center by the time they are three years old.

is consistent with siblings having more interactions that facilitate disease spread when their age difference is smaller, and with the older siblings—i.e., the ones who "bring home" disease—being more susceptible to infection when they are younger themselves (since the age of the older siblings observed in the right-hand graphs in Figure 3 is lower when the birth spacing gap is smaller).

Sibling differences in hospitalizations for other conditions. So far, we have focused our discussion on sibling differences in hospitalizations for respiratory conditions. But do such patterns exist for other types of hospitalizations? Appendix Figure A2 shows hospitalization rates among older and younger siblings during their first year of life with four additional categories of diagnosis codes: intestinal infectious diseases, other infectious diseases, non-infectious digestive diseases, and injuries and poisonings. The graph for respiratory diseases (Figure 1a) is replicated in the top left corner for comparison purposes. The figure makes clear that hospitalizations for respiratory diseases are much more common than hospitalizations for the other causes. Moreover, there are no sibling differences in hospitalization rates for intestinal infectious diseases, non-infectious digestive diseases, or injuries and poisonings. These patterns suggest that the sibling differences observed for respiratory illnesses are unlikely to be explained by differences in parental caretaking behaviors or in the tendency to go to the hospital conditional on having a health problem between first and second-born children. We do observe some sibling differences for the category of "other infectious disease," with higher rates of hospitalization for younger siblings during the first six months of life, suggesting that older siblings might "bring home" not only respiratory but also other infectious diseases. However, both the levels and the gaps in that category are much smaller than for respiratory diseases, motivating our focus on respiratory disease given its frequency and relevance during infancy.

3.2 Comparing Differences in Respiratory Disease Hospitalizations during Infancy with Differences in Age-30 Earnings

Figure 4 shows bar graphs of the differences in respiratory disease hospitalizations during infancy across birth order, season, and birth spacing side-by-side with the differences in annual

age-30 earnings across the same groups.[16] The earnings data are residualized from calendar year fixed effects to control for aggregate time trends. Across all panels, the groups with the highest rates of infancy hospitalizations experience the lowest earnings at age 30. Compared to their older siblings, younger siblings experience a roughly 2.0 percentage point higher hospitalization rate during their first year of life and earn around $800 USD less at age 30. A similar difference in relative magnitudes is observed between older and younger winter-born siblings, and between younger siblings born in the winter compared to those born in non-winter months. Infancy hospitalization and adult earnings differences are less pronounced between younger siblings with birth spacing gaps above and below three years, but relative magnitudes of the hospitalization and earnings differences are again in a similar range.

3.3 Summary of Descriptive Analysis

The analysis of differences in respiratory disease hospitalizations during the first year of life by birth order, birth season, and birth spacing has demonstrated three stylized facts: (i) higher hospitalization rates among younger siblings than older siblings when observed at the same age, (ii) a larger sibling hospitalization gap during the winter season, and (iii) a larger hospitalization gap for more closely spaced siblings. These patterns are consistent with the idea that respiratory disease spreads within the family because older children "bring home" viruses that they pick up in their local community (e.g., at their childcare center).

The fact that the differences in age-30 earnings follow a similar pattern as those for respiratory hospitalizations during infancy provides some indication of a possible causal link between these two variables. Putting together the two sets of descriptive analyses, we can conclude that an additional respiratory hospitalization during the first year of life per 100 children is associated with around $400 USD lower annual earnings at age 30. We note that since hospitalizations likely reflect the most severe cases of respiratory illness, one should not view this association as reflecting the relationship between infancy hospitalization and adult income, but rather an estimate of the average earnings loss among all sick infants (both those who were and were not hospitalized). Moreover, a causal interpretation of this association relies on the assumption that any earnings differences by birth order (and the interactions with

[16] Appendix Figure A3 shows Panels B and C including graphs the older sibling.

birth season and birth spacing) are only driven by differences in respiratory illness during the first year of life. This assumption is unlikely to hold as birth order, season, and spacing may have independent effects on later outcomes through various channels, including differences in parental investments (Black et al., 2005), seasonality of *in utero* conditions (Currie and Schwandt, 2013), and relative age at school entry (Black et al., 2011). For that reason, we develop a quasi-experimental approach in the next section which leverages spatial and temporal variation in local disease outbreaks during children's first year of life in conjunction with the variation in respiratory disease exposure between older and younger siblings just described.

4 Empirical Strategy for Estimating Causal Effects of Early Life Respiratory Disease Exposure

Our main independent variable is designed to capture respiratory disease exposure during the first year of life from slightly older children in the local community. We begin by using the *National Patient Register* data to obtain the number of respiratory disease hospitalizations per 100 children aged 13 to 71 months in each municipality and calendar year-month over our analysis time frame.[17] To allow for an informative visualization of the variation in this respiratory hospitalization rate, in Appendix Figure A4, we plot the raw month-by-month values of the rate in each of Denmark's 10 most populated municipalities, separately over four time periods during our sample time frame: 1980–1989, 1990–1999, 2000–2009, and 2010–2016. Consistent with our descriptive analysis above, we observe a strong seasonal pattern, with a higher hospitalization rate during the winter months in all locations and across all time periods. At the same time, there is a substantial amount of variation in children's respiratory hospitalizations across municipalities in any given month, as well as within each municipality over time. In Appendix Figure A5, we demonstrate the central source of variation used to identify the key estimates in our empirical model (described in more detail below)—we use data for all municipalities in Denmark for the entire sample period, regress the hospitalization rate on municipality and year-month fixed effects, and plot the distribution of the residuals.

[17] We use 71 months (i.e., 5 years and 11 months) as the upper age limit to capture respiratory disease spread among preschool-aged children, most of whom are in group childcare environments. Children start primary school at age 6 in Denmark.

The figure demonstrates that there remains a substantial amount of variation in respiratory disease hospitalizations even after location and time fixed effects are partialled out.

Next, for each child in our sibling analysis sample, we assign this monthly respiratory hospitalization rate to each month of their first year of life based on their municipality of residence in that month. Importantly, if a given child has an older sibling who is between 13 and 71 months of age at any point during their first year of life, we exclude the older sibling from the hospitalization rate. Finally, we define the disease exposure index as the sum of the monthly hospitalization rates over the 12 months of each child's first year of life. Thus, our index captures a child's cumulative respiratory disease exposure before age one from slightly older children in their municipality.

Our empirical models estimate the differential effect of the respiratory disease exposure index on younger versus older siblings. Specifically, our regression models take the form:

$$Y_{itm} = \beta_0 + \beta_1 Younger_i + \beta_2 Index_{itm} + \beta_3 Younger_i \times Index_{itm} + \mu_m + \theta_t + \gamma' X_i + \epsilon_{itm} \quad (1)$$

for each child i born in year-month t, and municipality m. Y_{itm} is an outcome such as the number of hospitalizations during the first year of a child's life that have a primary diagnosis of a respiratory condition, or gross personal income at ages 25–32. $Younger_i$ is an indicator set to 1 for younger siblings, and captures the "main" effects of birth order on our outcomes of interest. $Index_{itm}$ is the respiratory disease exposure index described above. μ_m are municipality fixed effects that account for time-invariant geographic differences in exposure to infectious diseases and in other determinants of our outcomes. θ_t are birth year-month fixed effects that control for cohort and seasonal trends. X_i is a vector of individual and family background control variables measured in the year of birth: indicator for the child being male, indicators for low birth weight (less than 2,500 grams) and very low birth weight (less than 1,500 grams) births, the birth spacing between siblings in months and birth spacing interacted with the younger siblings indicator, mother's age and age squared, indicator for mother's foreign-born status, indicators for mother's education level (high school degree, college degree or higher), and an indicator for parents being married or cohabiting. We also control for the natural log of the mother's, father's, and total family income, as well as indicators for each parent being employed, in the year before childbirth. We cluster standard errors at the

municipality level.

Identifying assumption. The key coefficient of interest in model (1), β_3, measures the differential impact on younger siblings relative to older siblings of an additional respiratory disease hospitalization per 100 children aged 13–71 months in the child's municipality during their first year of life. Interpreting this coefficient as representing a causal impact of respiratory disease exposure relies on an assumption that there are no unobserved municipality-specific time-varying factors that are: (a) correlated with respiratory disease prevalence, (b) influence children's outcomes, and (c) differentially impact younger versus older children in a family. While this assumption is not directly testable, we assess its plausibility in several ways.

First, we investigate the sensitivity of our main results across specifications that include different sets of control variables, including municipality-specific linear trends and maternal fixed effects. As we show below, our results are fairly robust across these models.

Second, we estimate model (1) without the controls in X_i and instead using the X_i variables as outcomes (Pei et al., 2019). Results are presented in Appendix Table A2. We find that three out of the 13 interaction coefficients reported in this table are statistically significant but very small in magnitude—mothers of younger siblings are slightly older and slightly more likely to have a college education, and the parents are slightly less likely to be married or cohabiting when the younger sibling is exposed to higher respiratory disease index. The 25th to 75th percentile effect sizes are smaller than one percent of the sample mean in all cases, suggesting that these predetermined characteristics play at most a very minor role. Nevertheless, we control for maternal age, education, and parental marital/cohabitation status in all of our analyses.

Third, we construct two alternative indices, in which instead of using children's hospitalizations for respiratory conditions, we use: (i) non-infectious digestive diseases, and (ii) injuries and poisonings. If the differential likelihood of hospitalization for respiratory conditions for younger compared to older children reflects differences in parental healthcare-seeking behavior (i.e., parents are more likely to go to the hospital with their second-born than their first-born at the same level of underlying illness), then we might expect similar patterns to emerge for other *non-infectious* childhood health shocks, such as those stemming from diges-

tive issues or accidents. Yet when we estimate model (1) using the two alternative indices and hospitalizations in the first year of life for these causes, we do not find evidence in support of this hypothesis (see Appendix Tables A3 and A4): we do not find any significant positive interactions between the alternative indices and the younger child indicator.[18]

Overall, these analyses support our identifying assumption, and suggest that our model is likely to yield causal estimates of the differential effects of respiratory disease exposure in infancy for younger relative to older siblings.

Selection into the siblings sample. The respiratory disease environment during the firstborn child's first year of life could influence parents' subsequent fertility decisions. This, in turn, could affect the selection into our sample which is restricted to sibling pairs (i.e., it excludes families with only one child). We explore such potential effects in Appendix Table A5, where we do not restrict our attention to families with at least two children, and use the following outcome variables: an indicator for having a second child, the birth spacing in months, and indicators for the second child being born in different seasons during the year. The main coefficient of interest is on the respiratory disease index observed during the first child's first year of life. Column (1) shows that a higher disease index during the infancy of the firstborn child reduces the probability of a second child being born, though the effect size is very small. This is consistent with the idea that a small number of parents who experience a high amount of illness during their firstborn child's first year of life may be deterred from having subsequent children. Since our estimates are based on comparisons between older and younger siblings and not intended to inform about effects on only children, this sample selection is not a concern for the validity or the generalizability of our results. Columns (2) to (6) of Appendix Table A5 show that the disease index is not associated with birth spacing or the timing of the second birth in terms of the birth season.

Sample means. Table 1 presents means of some of the key variables in our analysis, separately for the older and younger siblings in the sample. It shows that mothers are on average aged 26.9 years at the time of their first birth and 30.4 years at the time of their second

[18]Note that the highly significant main effects of the injury index on injury hospitalizations are plausible, as they are likely driven by underlying local and seasonal factors (e.g., icy conditions may increase the local injury rate among children).

birth. Approximately 4.7 percent of mothers in our sample are foreign-born. About 75.2 and 79.1 percent of mothers have a high school degree at the time of the first and second birth, respectively, while 30.9 and 37.4 percent have a college degree, respectively. Approximately 93.4 percent of parents are married or cohabiting at the time of the first birth, while 94.9 percent are married or cohabiting at the time of the second. Household income is slightly higher at the time of the second than the first birth.

The table highlights some important differences in child outcomes by birth order. Compared to older siblings, younger siblings have higher average birth weight (3,590 versus 3,431 grams for younger versus older siblings, respectively). The average values of the respiratory disease exposure index for older and younger siblings are similar: 2.8 and 2.9 hospitalizations per 100 children, respectively. However, despite the slight advantage in health at birth (which has been found in other settings, see, e.g. Brenøe and Molitor, 2018; Pruckner et al., 2021) and similar local exposure to respiratory disease, younger siblings' average number of hospitalizations for respiratory conditions during their first year of life is nearly *twice* the average for older siblings (9.28 and 4.71 per 100 children for younger and older siblings, respectively). The relative difference is even larger for RSV hospitalizations during the first year of life, with younger siblings' average number of hospitalizations *three times higher* relative to older siblings.[19] Moreover, consistent with prior literature on the impacts of birth order (e.g., Black et al., 2005), younger siblings have worse educational outcomes than their older counterparts. Additionally, younger siblings have higher rates of mental health care utilization, as measured by psychiatric hospital visits and visits to private psychiatric clinics.

5 Results

In this section, we first discuss our results on the relationship between the respiratory disease index and hospitalizations for respiratory conditions during infancy, for younger versus older siblings. We then discuss our results on long-run income and labor market outcomes, which we can measure through age 32 in our data. We follow up by benchmarking the magnitudes of

[19]The average number of hospitalizations for all respiratory conditions among the 1994+ cohorts, for whom we observe RSV-specific hospitalizations, is similar to the overall sample that includes older cohorts: 10.3 and 4.6 per 100 children for younger and older siblings, respectively.

our long-run estimates against those found in the prior literature, and provide some additional sensitivity and heterogeneity analyses. We finally present our results on educational outcomes, respiratory conditions, and mental health care utilization in adolescence and young adulthood.

5.1 Short-Term Effects of Respiratory Disease Exposure on Respiratory Hospitalizations

Table 2 presents results from estimating equation (1) using as the outcome the number of hospitalizations during the first year of a child's life that have a primary diagnosis of a respiratory condition. We report the coefficients on the indicator denoting the younger sibling, the respiratory disease exposure index (expressed as the number of respiratory disease hospitalizations per 100 children aged 13 to 71 months), and the interaction of these two variables. Column (1) shows that, consistent with the graphical evidence in Figures 1 through 4, younger siblings on average have 0.041 more (58.6 percent relative to the sample mean) hospitalizations for a respiratory condition before age one than their older counterparts. Column (2) shows that there is a positive correlation between the disease exposure index and the likelihood of hospitalization before age one in the overall siblings sample, and column (3) demonstrates that the coefficients on the younger sibling indicator and the disease exposure index do not change when they are both included in the same regression model.

Once we include the interaction term in column (4), we find that there is a larger effect of local respiratory disease exposure on younger siblings compared to older siblings. At the same time, the coefficient on the main effect for the younger sibling indicator drops by more than 80 percent, suggesting that the differential disease environment explains a large share of the overall birth order effect shown in column (1). Column (5) shows our preferred specification that controls for family background characteristics. We find that an additional respiratory hospitalization per 100 children aged 13–71 months in a municipality increases the younger sibling's number of hospitalizations during the first year of life by an average of 0.013 (18.6 percent), as compared to the older sibling.[20] In the bottom row of the table, we report the

[20]Note that the coefficient on the younger sibling main effect in column (5) is 0.042 which is comparable to the coefficient in column (1). However, column (5) includes family controls and when these are added to the specification in column (1) the coefficient on the younger main effect is 0.078. Hence, the main birth order effect becomes much smaller when the disease index interaction is added in models both with and without

magnitude of the differential effect on younger siblings relative to older siblings of an increase in the disease exposure index from the 25th to the 75th percentile of the index distribution (i.e., the interquartile effect size). This magnitude amounts to a 0.024 differential increase in the number of respiratory disease hospitalizations in the first year of life, which represents an additional 34.3 percent relative to the sample mean.

In Appendix Table A6, we explore the extent to which RSV contributes to the overall impact of respiratory disease. The table is identical to Table 2, except that we study the number of hospitalizations during the child's first year of life with an RSV diagnosis as the outcome (using cohorts born in 1994 or later), and we use an RSV-specific index instead of an index capturing all respiratory-related hospitalizations. We estimate that an additional RSV hospitalization per 100 children aged 13–71 months in a municipality increases a younger child's number of RSV hospitalizations in the first year of life by an average of 0.045 more than their older sibling's RSV hospitalizations at the same age. Moving from the 25th to the 75th percentile of the RSV index distribution amounts to a 0.005 differential increase in the number of RSV hospitalizations, or 27.8 percent at the sample mean. Thus, early-life RSV exposure could be an important driver of the adverse impacts on long-term outcomes that we describe next.

5.2 Long-Term Effects of Infancy Respiratory Disease Exposure on Adult Income and Labor Market Outcomes

Figures 5-6 report the differential long-term effects of infancy disease exposure for younger relative to older siblings, using our main income and labor market outcomes defined in Section 2: labor force participation, wage earnings (conditional on employment), gross personal income, and relative income rank, all measured at ages 18–32. We plot the coefficients and 95% confidence intervals on our key interaction term from separate models that use the outcomes measured at the ages listed on the $x-$axis as dependent variables. Appendix Tables A7-A8 report the full set of coefficients and standard errors for the younger sibling indicator, the respiratory disease index, and the interaction term.

The results in Figure 5(a) suggest that infancy exposure to respiratory disease is not

family controls.

associated with a differential effect on the likelihood that the younger sibling is observed in the labor force at the reported ages. Thus, there does not appear to be much evidence of an effect on labor supply on the extensive margin. At the same time, Figures 5(b) and (c) document significant wage losses for the younger siblings that appear at age 26, strengthen at age 27, and remain significant at a similar magnitude until age 32, at the end of the sample age range. The magnitudes of the effect sizes indicate that an increase in infancy disease exposure by one additional respiratory hospitalization per 100 children aged 13–71 months in a municipality is associated with a wage loss of around $500 USD, or around 1 percent of baseline income. Before age 26, effects on earnings are negative but not statistically significant. The earnings measure reported here is conditional on employment, which could explain the lack of significant effects during the early 20s when many young adults in Denmark have not yet joined the labor force.

Figure 6(a) reports effects on total income, which includes transfers (e.g., stipends for university students) and is strictly positive for virtually the entire population. We observe significant negative effects on total income appearing at age 18, and these effects become much stronger around age 26, following a similar pattern as the wage results. Figure 6(b) shows effects for log income, indicating that in relative terms, the large effect materializes by age 18 and remains at a similar level of around one percent going forward.

Lastly, in Figure 6(c), we show estimated effects on individuals' income rank relative to their cohort. Similar to the results for log income, relative income rank is impacted at age 18, and the effect remains significant and at a similar magnitude throughout the entire analyzed age range. Overall, these figures consistently suggest that early-life respiratory disease exposure leads to an income penalty in adulthood for the younger sibling.

In order to summarize the effects estimated at different ages, in Tables 3 and 4, we report results from our baseline model pooling across income measured at ages 25–32.[21] The tables also report specifications that only include the birth order main effect in order to assess how much the birth order effect changes once we include the disease index interaction.

We find that an additional respiratory hospitalization per 100 children aged 13–71 months in an individual's municipality in the first year of life reduces the younger sibling's average

[21] Here, we use data at the person-by-age level, and study the outcome at ages 25–32. These models include age fixed effects and cluster standard errors on the municipality and individual level.

wage income by $235 USD or 0.6 percent (columns 4 and 6 of Table 3). The impacts on total income are in a similar range, with an estimated decline of $193 USD or 0.6 percent (columns 2 and 4 of Table 4). Column (6) of Table 4 shows that an additional respiratory hospitalization per 100 children aged 13–71 months in a municipality reduces a younger child's income rank at ages 25–32 by about a quarter of a percentile.

Figure 7 explores the impacts of infancy exposure to respiratory illness on income rank in more detail. We show coefficients and 95% confidence intervals on our key interaction treatment variable from models that use as outcomes indicators for being in different bins of the Danish income distribution within each birth cohort (where income is measured over ages 25–32): the 1–10th percentiles, the 11–25th percentiles, the 26–50th percentiles, the 51–75th percentiles, the 76–90th percentiles, and the 91–100th percentiles. We find a shift down from the top of the distribution: we see negative coefficients on the likelihoods of being in the highest three bins of the income distribution and positive coefficients on the likelihoods of being in the lowest three bins of the income distribution. In particular, younger siblings exposed to more respiratory disease in the first year of life are significantly more likely to be in the bottom decile of the Danish income distribution.

The distributional impacts that we find differ somewhat from those identified in prior research on other types of early childhood shocks. For example, Isen et al. (2017b) find that reduced exposure to air pollution in the first year of life due to the Clean Air Act Amendments is associated with a shift from the bottom to the middle of the earnings distribution among US adults, but has no effect at the top of the income distribution. While there are many reasons that could explain the difference in these patterns, one possibility is that the early-life shock that we study—exposure to common respiratory viruses in infancy—is more universally prevalent across families with from different socio-economic backgrounds than a shock like policy-driven reduction in air pollution exposure, which disproportionately affects disadvantaged populations (Currie et al., 2023). Thus, our results suggest that even for children born in families that are relatively protected from many adverse shocks due to their advantaged position in society, severe respiratory illness in early infancy can lower the likelihood that they end up at the top of the income distribution as adults.

5.3 Robustness to Alternative Modeling Choices

We examine the sensitivity of our main results across different specifications and different ways of measuring respiratory disease exposure. Appendix Table A9 provides results from sensitivity analyses of short-term effects while Appendix Tables A10–A15 present sensitivity results for long-run income and labor market outcomes. For tractability, we study average adult outcomes across ages 25–32.[22] Column (1) of each table presents the baseline model in which we include municipality and birth year-month fixed effects, and family background controls. Column (2) adds municipality-specific linear time trends to account for differential trends in outcomes across municipalities, while column (3) adds maternal fixed effects that eliminate potential bias from unobserved genetic and family characteristics common among siblings.

The remaining columns check the robustness of the results to alternative ways of constructing the disease index. In our baseline analysis, the respiratory disease index is based on the number of hospitalizations with a primary diagnosis of a respiratory condition. Column (4) calculates the disease index based on the number of hospitalizations including both primary and non-primary diagnoses for respiratory conditions. In column (5), we construct the disease index based on the number of children with at least one primary respiratory disease diagnosis (i.e., we count the number of children rather than the total number of hospitalizations). Our results are highly robust across these different modeling choices.

5.4 Comparing Magnitudes of Long-Term Effects to Existing Literature

How do our estimated effects on long-run income compare to those documented in the prior literature on early childhood shocks? As noted above, we find that moving from the 25th to the 75th percentile of the respiratory disease index distribution is associated with an additional 0.9 percent reduction in adult income for second-born children. This effect size is similar to a one percent earnings reduction in response to a 10 percent reduction in birth weight (Black et al., 2007) or the one percent adult earnings in response to a nine percent reduction in ambient

[22] As discussed earlier, we use data at the person-by-age level and the models include age fixed effects and cluster standard errors on the municipality and individual level.

air pollution in one's year of birth (Isen et al., 2017b). It also corresponds to almost two-thirds of the effect of *in utero* exposure to the 1918 Spanish Influenza pandemic (Almond, 2006) and one-fourth of the effect of *in utero* exposure to a maternal influenza infection that requires hospitalization (Schwandt, 2018).[23]

It is additionally helpful to compare our estimates to those found in studies evaluating policies that reduce disease prevalence in the population. For example, Bhalotra and Venkataramani (2015) find that moving from the 75th to the 25th percentile in the pneumonia infection rate following the introduction of sulfa drugs leads to a 2.1 percent increase in adult income among exposed cohorts. Atwood (2022) and Chuard et al. (2022) find that the introduction of universal childhood measles vaccine lead to a 1.7 to 2.7 percent increase in adult family income among cohorts who benefited from the vaccine. Bütikofer and Salvanes (2020) document a 0.8 percent increase in adult income for cohorts who were in school during and after a tuberculosis control campaign in Norwegian municipalities that had above-median pre-campaign tuberculosis levels.

We can also benchmark our estimates against the literature on birth order. Black et al. (2005) find an earnings disadvantage of 1.2 to 4.2 percent for second-born siblings compared to those who are first-born. Our birth order effect is within this range: we find a 2.4 percent difference for wages conditional on employment and a 2.3 percent difference for total income between younger and older siblings in regressions that exclude the interaction term between the respiratory disease index and the younger sibling indicator (column (5) of Table 3 and column (3) of Table 4). However, when the interaction term is included, the main effect of birth order decreases by around 50 percent across all income measures. This result suggests that an important part of the overall birth order effect on income could be explained by the second-born child's higher exposure to respiratory disease during infancy.

5.5 Treatment Effect Heterogeneity

We next explore heterogeneity in our estimates. We first study differences in impacts across subgroups, defined by parental socio-economic status (measured as the mother's years of

[23]Note that our estimates represent intent-to-treat effects as not every child gets sick in response to exposure to a higher respiratory disease index.

education being above or below the median in the distribution), child health at birth (low-birth-weight and non-low-birth-weight children), and the younger sibling's gender. For our short-term analysis of respiratory hospitalizations before age one, we further investigate heterogeneity by the birth spacing between the siblings, and whether or not the older child is enrolled in a childcare center (limited to siblings with a birth spacing gap of no more than 2 years).[24] For these analyses, we estimate our baseline model (1), and include subgroup indicators interacted with the younger sibling indicator, the disease index, and the younger sibling indicator $\times$ disease index interaction. We then plot the coefficients and 95% confidence intervals from estimates of the triple interaction terms.

Short-term effect heterogeneity. The results in Appendix Figure A6 show that the effects on respiratory hospitalizations are larger for younger siblings who are low birth weight than those who are not. Additionally, consistent with the "fragile male" hypothesis regarding the biological vulnerability of male fetuses and infants (McCarthy, 2019; Sanders and Stoecker, 2015; Kraemer, 2000), we find larger impacts on younger male than female siblings.[25]

We also observe that the impact on respiratory hospitalizations appears to be monotonically decreasing with birth spacing—that is, younger siblings in families with a shorter birth spacing period experience larger differential impacts on hospitalizations in the first year of life. This pattern is consistent with the descriptive evidence presented in Figure 3, and speaks in favor of the mechanism of intra-family spread as being a key driver of respiratory disease among younger infant siblings. Further, these results suggest that our effects are *not* driven by differences in parental investments between older and younger siblings (and the potential interactions between these investments and our disease index). As documented by Price (2008) in the U.S. setting, there are important differences in parent-child quality time between first- and second-born children, but this difference is larger when the birth spacing gap is greater. Thus, our pattern is the opposite of what would be predicted if differential parental time investment were the main channel.

[24] From age 3 onwards, the vast majority of children are enrolled in a childcare center (see Appendix Figure A1). Additionally, the heterogeneity by childcare enrollment analysis sample is limited to sibling pairs born between September 1995 and September 2013, which is the period of time covered by our childcare enrollment data.

[25] We do not find any evidence of heterogeneity by the older child's gender.

Lastly, we find that the effects on respiratory hospitalizations among younger siblings are larger in sibling pairs with a short birth spacing in which the older child is in a childcare center than in pairs in which the older child is not. This result provides further support for our hypothesized mechanism of spread—that the older sibling gets exposed to respiratory disease while in group childcare, and then "brings it home" to their more vulnerable younger brother or sister.

Long-term effect heterogeneity. Appendix Figure A7 presents heterogeneity results for long-run income and labor market outcomes. Overall, we do not find any statistically significant differences in long-term effects by maternal education, child birth weight, or gender.[26] While there are some patterns of subgroup differences across outcomes, confidence intervals are too large to reach statistical significance, perhaps due to the smaller sample size used in our long-run analysis. Suggestively, male younger siblings appear to be more affected across all outcomes than female younger siblings, which is in line with the heterogeneity observed in the short-term analyses of respiratory hospitalizations. In terms of differences by socioeconomic status (as proxied by maternal education), if anything, it appears that the effects are slightly larger for younger siblings in higher-SES than lower-SES households. One potential explanation could be that higher-SES children are exposed to fewer other adverse shocks than lower-SES children, and so the marginal effect of this (relatively universal) shock is larger.

Heterogeneity by exposure earlier versus later in the first year of life. We also explore heterogeneity in impacts depending on the child's age in months at the time of exposure. The descriptive patterns shown in Figure 1 indicate that the hospitalization gap between younger and older siblings is particularly large during the first few months of life compared to the later months of the first year of life. This pattern may be due to the increased vulnerability of very young infants because of their still-developing immune systems, i.e., there is a higher likelihood of developing a severe respiratory infection in the very early months of life compared to at slightly older months. We would then also expect disease exposure during

[26]Note that we cannot study heterogeneity by birth spacing or childcare attendance because of data constraints. Our long-run models require both of the siblings to be observed in the data, i.e., when we pool ages 25–32, we require both siblings to be observed for each age between 25 and 32. This restricts the sample cohorts to those born between 1987–1994, and we do not have enough observations of sibling pairs with long birth spacing gaps. Moreover, there is no data on childcare attendance for these older cohorts.

the first months of life to have stronger long-term effects. Alternatively, higher hospitalization rates during the first months could reflect a stronger response by the healthcare system for any given illness.[27] In that case, a given disease exposure should have less severe long-term effects during the first months of life as long as the increased healthcare response is beneficial.

We try to disentangle these two explanations by considering differences in effects across infants for whom exposure is measured earlier versus later in the infancy. Appendix Tables A16 and A17 show results from regressions in which we replace the baseline disease index defined over the entire first year of life with a disease index defined over the first six months and the second six months, respectively. In line with the patterns in Figure 1, the short-term impacts on hospitalization are about twice as large for a given level of respiratory disease exposure during the first half compared to the second half of a younger sibling's first year of life (Appendix Table A16). We also find stronger effects of exposure during the first six months for our long-term outcomes. All four labor market and income outcomes shown in Appendix Table A17 are consistently impacted about twice as much by a given increase in the disease index during the first compared to the second half of the first year of life of the younger sibling. These patterns suggest that indeed infants are particularly vulnerable to disease exposure during the first months of life, and that the healthcare system does not sufficiently buffer against this increased vulnerability.

5.6 Additional Outcomes and Potential Pathways

In this section, we study several other outcomes measured in later childhood and young adulthood that may shed light on how the observed deterioration in short-run respiratory health could adversely affect adult income.

Long-term effects on respiratory hospitalizations. It is also possible that individuals who experience adverse respiratory health in infancy experience lasting damages to their respiratory system, which, in turn negatively influences adult earnings capacity (e.g., maybe they need to take more time off work due to physical health issues). At the same time, it is possible

[27] For example, in the United States, the current medical guidance is that infants under 3 months of age are to be brought to the ED if they have any fever. For infants between 3 and 6 months of age, only a fever of 102°F or higher is indicated for ED care. For infants between 6 and 12 months of age, only a fever of 102°F or higher that lasts more than 24 hours is indicated for contacting the healthcare system.

that early respiratory disease exposure in fact strengthens the immune system, resulting in improved health at later ages. In Figure 8, we examine the effects of respiratory disease exposure in infancy on respiratory hospitalizations at later ages. As before, we plot the coefficients and 95% confidence intervals on our key interaction treatment variable from separate models that use as outcomes the annual number of respiratory disease hospitalizations, measured at different ages denoted on the $x-$axis. The figure shows that the large positive effect during the first year of life is followed by significant negative effects at ages two and three, in line with a protective effect of earlier disease exposure. However, this reverse effect disappears by age four and, if anything, positive effects are observed in later adolescence and early adulthood. These results suggest that there is no protective effect of infancy infections against severe respiratory illness in later childhood and adolescence. At the same time, there is no evidence of impaired respiratory health in the long run, making it unlikely that this is a critical channel for the observed long-term income effects.

Long-term effects on educational outcomes. Impacts on the accumulation of human capital could be another important pathway through which infancy disease exposure could affect adult economic outcomes. Figure 9 presents effects of infancy exposure to respiratory diseases to high school completion and college graduation, by ages 18–32, respectively. As with the results on our income and labor market outcomes, we plot the coefficients and 95% confidence intervals on our key interaction term from separate models that use outcomes measured at the ages listed on the $x-$axis as dependent variables. Corresponding regression results are reported in Appendix Tables A18. In Figure 9(a), we document a significant negative effect of around half a percentage point at age 20 and 21, but the coefficients are close to zero and not statistically significant at older ages. These patterns suggest that affected younger siblings have lower high school graduation rates initially, but that there is later catch-up and no significant impact on high school completion in the long run. We observe a similar pattern for college graduation in Figure 9(b) with initial negative effects of around half a percentage point around the time of typical graduation from college, and subsequent catch-up and no significant long-term impacts.

Appendix Table A19 shows regressions using as outcomes the standardized 9th grade

Danish and mathematics test scores, respectively. We find that an additional respiratory hospitalization in the municipality per 100 children aged 13–71 months reduces the 9th grade Danish and math test scores by about 0.008 and 0.003 of a standard deviation more for younger siblings than older siblings, respectively. But while the effect on the Danish test score is marginally significant at the 10% level, the coefficient for the math test score is not statistically significant at conventional levels.[28]

Overall, the analysis of educational outcomes suggests that there are some delays in educational attainment with subsequent catch-up, while effects on 9th-grade test scores are small and not precisely estimated. It therefore seems unlikely that deterioration of educational attainment is a major channel linking infancy respiratory disease exposure to adult economic outcomes.

Long-term effects on mental health care. Another potential pathway that has been discussed by the biomedical literature relates to brain development during infancy and later development of mental health issues (Eppig et al., 2010; Bhalotra and Venkataramani, 2013). Figure 10 and Table 5 present evidence that early-life respiratory disease exposure leads to increased mental health care utilization for the younger sibling, when measured at ages 16–26.[29] The first panel of Figure 10 shows positive effects on the number of psychiatric visits, either at a psychiatric hospital or at a private clinic, that grow in size and become statistically significant in the early 20s. The average effect across the analyzed age range amounts to 0.346 additional visits per year between 16 and 26 for each additional respiratory hospitalization per 100 children aged 13–71 months in an individual's municipality in the first year of life (see column (1) of Table 5). The interquartile effect size represents a 4.1 percent increase over the baseline mean. The effect on the extensive margin shown in column (2) is positive as well but not as precisely estimated. As shown in the second and third rows of Figure 10 and the remaining columns of Table 5, the effect on overall psychiatric visits is driven by visits to

[28] When we split our index based on exposure in the first six months of life versus the second half year of life, we find that the impact on 9th grade Danish test scores increases to -0.016 from -0.008 in the baseline regressions. The effects on math test scores increase as well with a point estimate of -0.012 for exposure during the first six months though the estimate remains insignificant (see Appendix Table A20).

[29] The more limited age range of mental health care outcomes as compared to educational and labor market outcomes stems from the fact that we observe psychiatrist visits for a more limited set of years. Appendix Table A21 reports the corresponding regressions.

private clinics which likely represent less severe cases than visits to a psychiatric hospital for which we do not find effects. In particular, we find that an increase in the disease index from 25th to 75th percentile increases the number of mental-health related private clinic visits by 5.5 percent and the likelihood of any private psychiatric clinic visit by 4.4 percent.

When we split our index based on exposure in the first six months of life versus the second half year of life, we find stronger impacts for the former. In particular, the effects on mental health clinic visits increase almost three-fold and become more significant (see Appendix Table A22).

The magnitudes of the effects on mental health that we estimate echo conclusions of other work documenting impacts of fetal and early childhood shocks on later mental health outcomes. Our effect sizes are smaller, likely because we study a less extreme shock in early life. For example, Almond and Mazumder (2011) find that exposure to Ramadan *in utero* leads to a near doubling of the incidence of mental and learning disabilities in adulthood in Uganda, and increases the rate of psychological disabilities in adulthood by 63 percent in Iraq. Persson and Rossin-Slater (2018) use data from Sweden, and find that experiencing the death of a close maternal relative while *in utero* is associated with a 25 percent increase in the likelihood of using ADHD medications around age 10, as well as 13 and 8 percent increases in the likelihoods of using drugs to treat depression and anxiety, respectively, around age 35. Adhvaryu et al. (2019) use a nationally-representative survey from Ghana, and show that a one standard deviation increase in the price of cocoa in one's year of birth—which improves the economic circumstances of Ghanaian families in cocoa-producing regions—reduces the likelihood of severe mental distress in adulthood by 3 percentage points, or about 50 percent at the mean prevalence rate.

6 Conclusion

Respiratory illnesses are very common among young children, especially in families with more than one child. Despite their regular occurrence, there is limited population-level evidence on the role of intra-family transmission, or on the long-term causal impacts of exposure to respiratory disease during infancy. This paper uses linked administrative data from Denmark

spanning four decades to document the importance of birth order in driving susceptibility to respiratory infection. We find that younger siblings are two to three times more likely to be hospitalized for respiratory conditions during their first year of life compared to the older siblings at the same age, and this disparity is especially large when hospitalizations are measured in the first three months of life. Additional analyses of the seasonality in hospitalizations and heterogeneity across siblings with different birth spacing gaps point to the importance of intra-family transmission in explaining this birth order effect: older children "bring home" common respiratory viruses (such as RSV), making their younger siblings susceptible to severe illness very early in life.

We then combine the birth order variation with variation in local respiratory disease prevalence to study long-term effects of early-life disease on adult economic, human capital, and health outcomes. We show that exposure to severe respiratory illness during infancy has negative consequences on economic outcomes in adulthood. We find that, for the younger siblings, moving from the 25th to the 75th percentile in the disease index distribution exposure in the first year of life leads to 0.8 and 0.9 percent reductions in wage earnings and overall income (conditional on employment) at ages 25–32, as well as a 0.3 percentage point reduction in the income percentile rank. We do not find evidence supporting the idea that impairments to human capital attainment or physical respiratory health are the key drivers of these long-run effects. Instead, our analysis suggests that impaired brain development, which leads to a higher incidence of mental health issues in young adulthood, could be an important channel. Future research should consider additional potential mechanisms underlying these long-term effects.

The long-term effects that we estimate represent the overall net impacts of respiratory disease exposure during infancy. Thus, these estimates incorporate any potential benefits associated with increased immunity, as well as parental responses to the health shocks. In sum, our findings suggest that policies mitigating the spread of respiratory diseases among very young children may have large long-term benefits, which are likely not incorporated into current cost-benefit evaluations.

The communal disease index that we develop could also be used in future research to study the impact of child sickness on other family members such as older siblings or parents. In

pioneering work Breivik and Costa-Ramón (2022) find that mothers experience costly and persistent career disruptions when their child dies or is hospitalized for a severe health condition. Our respiratory disease index, though based on other children's hospitalizations, proxies for less severe health shocks which are likely less disruptive to parents' work lives. At the same time, as respiratory diseases are very common the aggregate effects on parental labor market trajectories might be substantial. Aggregate impacts might further be amplified when the intra-household disease spread extends to parents' coworkers when they bring infectious diseases to their work place (Pichler and Ziebarth, 2017).

This study is also relevant for the assessment of the costs of the COVID-19 pandemic for young children. While children have been considered to be a low-risk group for infection with the SARS-CoV-2 virus, the pandemic may have lasting and dynamic impacts on children through its effects on other infectious diseases. Policies implemented during the pandemic—including travel restrictions and school closures—have reduced the spread of other respiratory viruses, such as RSV (Leung et al., 2020; Cowling et al., 2020). At the same time, the spread of RSV and other common respiratory viruses surged in 2021 and 2022 once the restrictions were lifted, reflecting a larger than usual susceptible population of young children who had been shielded during the early stages of the pandemic. Our results suggest that infants with older siblings may have benefited from the pandemic-induced muted disease spread during the first year of the pandemic, while those born during the following two years might have experienced stronger than usual disease exposure. Thus, the COVID-19 pandemic may have differential long-term effects on children born before and during the pandemic through its dynamic impacts on the spread of other infectious diseases that are more serious in early life than COVID itself, including RSV.

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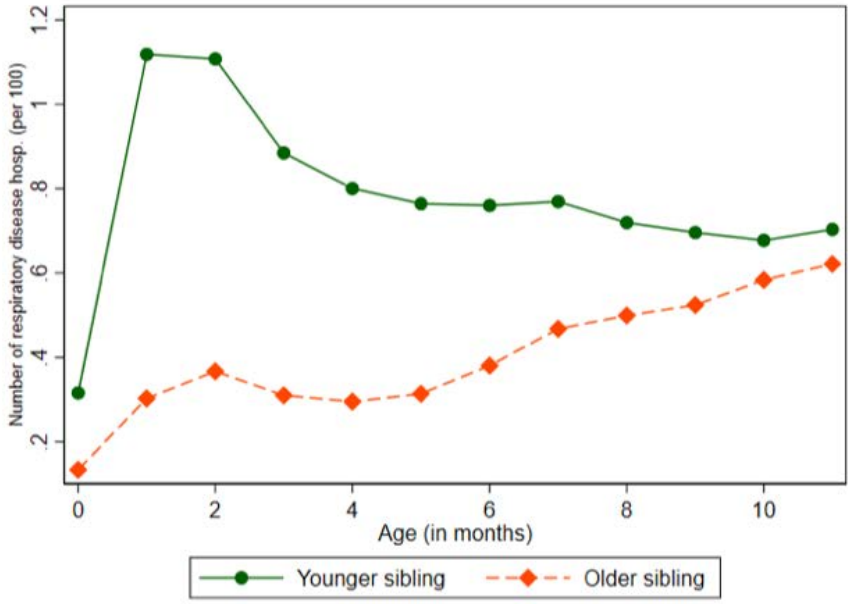
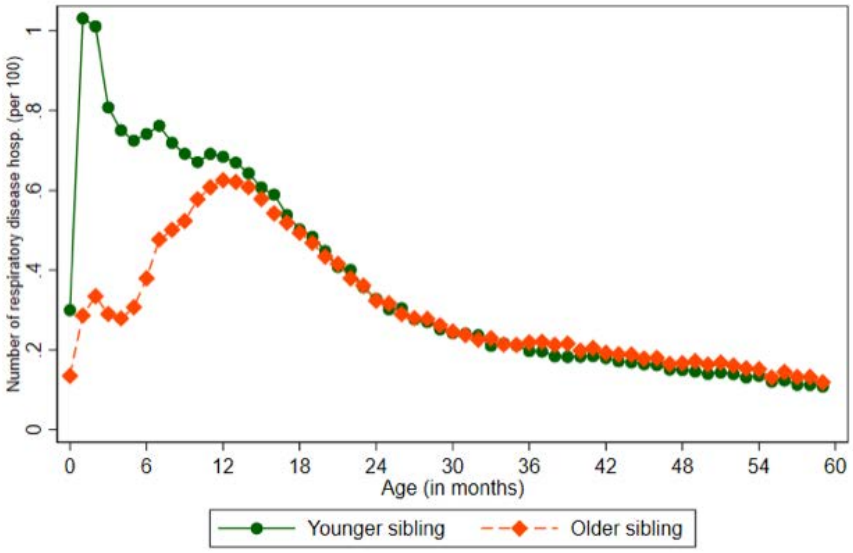
7 Figures

Figure 1: Number of Respiratory Hospitalizations per 100 Children, by Child Age in Months, Older versus Younger Siblings

(a) During First Year of Life

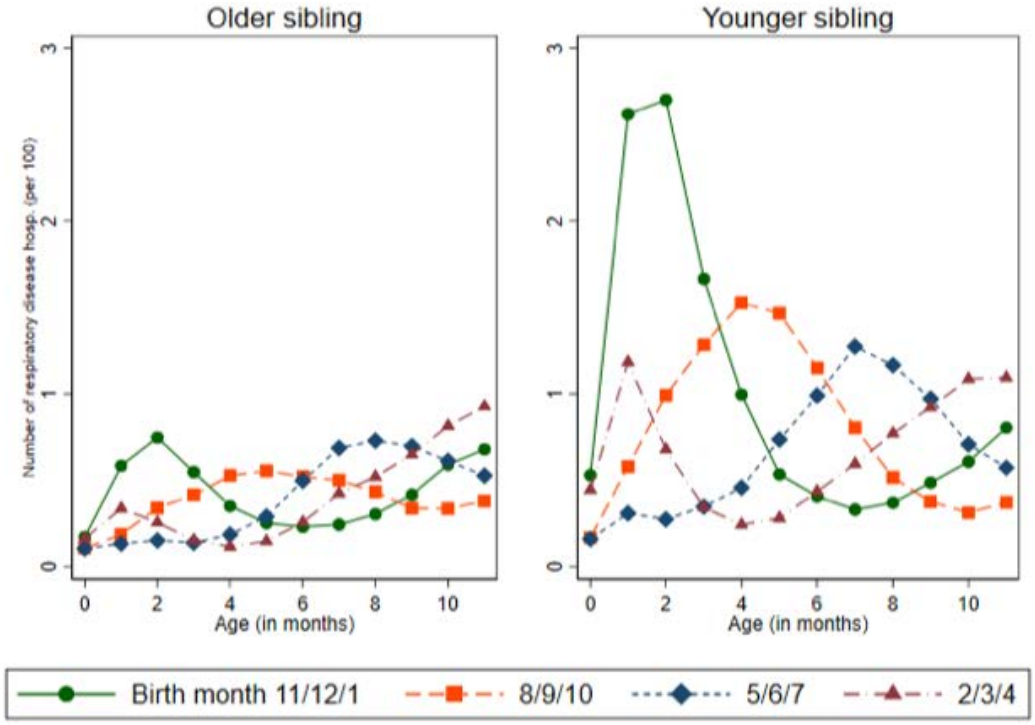


(b) During First Five Years of Life



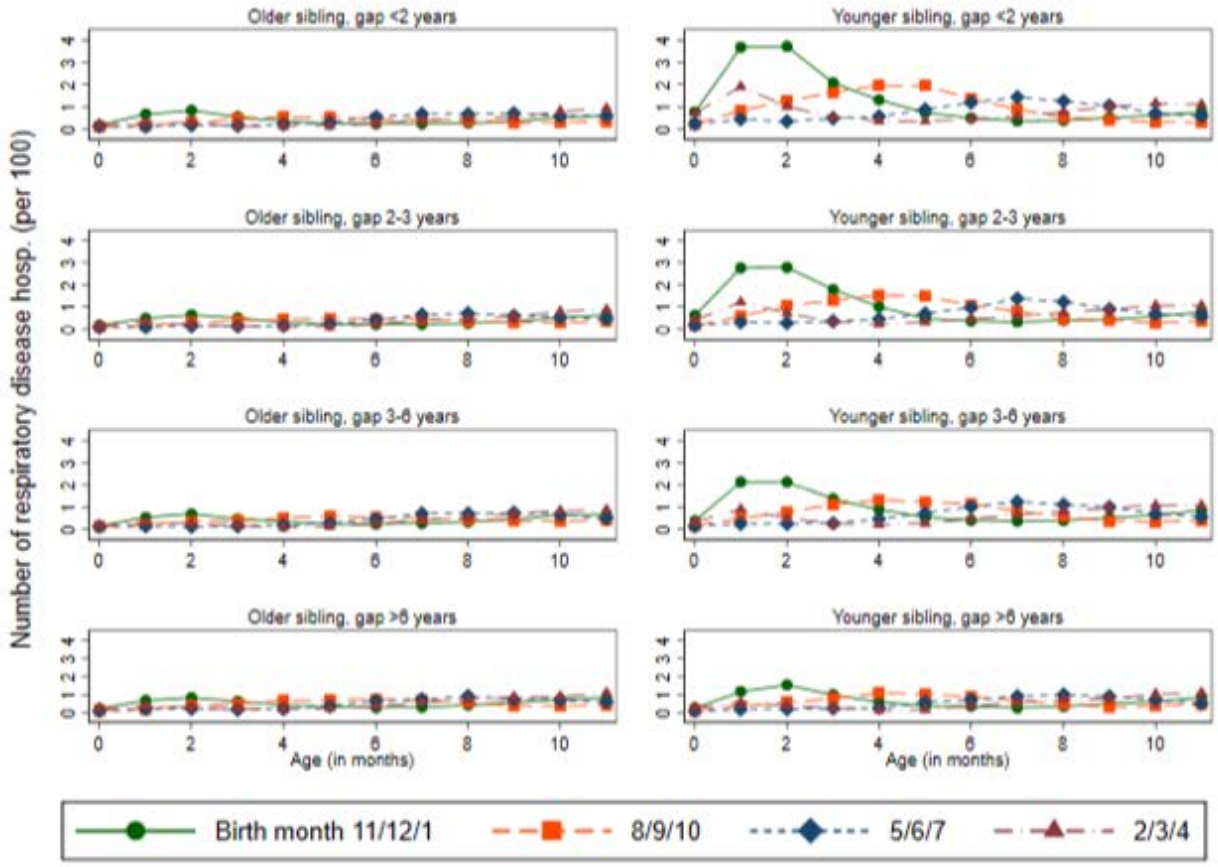
Notes: These figures plot the number of hospitalizations with respiratory illness diagnoses (per 100 children) by month of age, separately for older and younger siblings in our data.

Figure 2: Number of Respiratory Hospitalizations per 100 Children, by Child Age in Months and Season of Birth, Older versus Younger Siblings



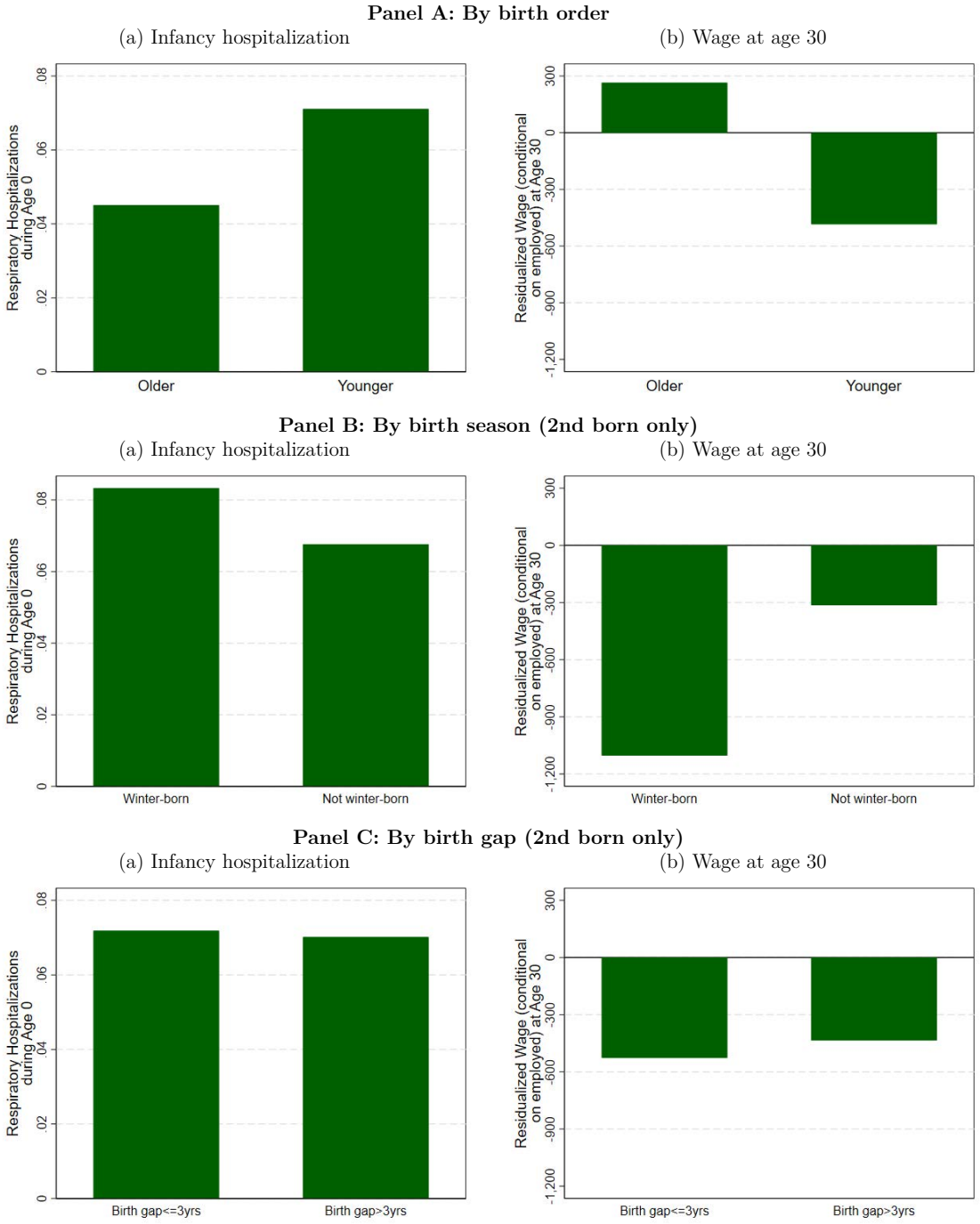
Notes: These figures plot the number of hospitalizations with respiratory illness diagnoses (per 100 children) by month of age and by the season of birth of the child, separately for older and younger siblings in our data.

Figure 3: Number of Respiratory Hospitalizations per 100 Children, by Child Age in Months, Season of Birth, and Birth Spacing, Older versus Younger Siblings



Notes: These figures plot the number of hospitalizations with respiratory illness diagnoses (per 100 children) by month of age and by the season of birth of the child, separately for older and younger siblings with different birth spacing gaps in our data.

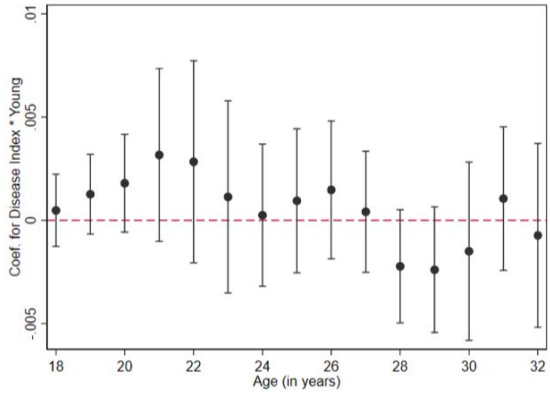
Figure 4: Respiratory Hospitalizations during First Year of Life and Residualized Wage at Age 30



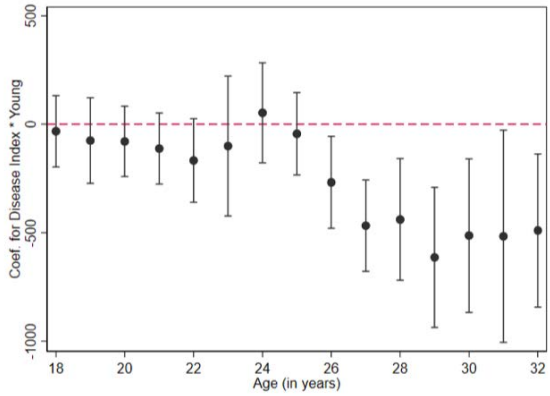
Notes: These figures plot the number of hospitalizations with respiratory illness diagnoses during age 0 and residualized wage income (conditional on employment) at age 30, by birth order, birth season, and birth gap. The sample includes first- and second-born sibling pairs born from 1981 to 1989. Wage income is measured at age 30 and residualized after controlling for year fixed effect. "Winter-born" refers to children born in November, December, and January.

Figure 5: Effects of the Respiratory Disease Exposure Index on Younger Siblings' Labor Force Participation and Wage, by Age of Observation

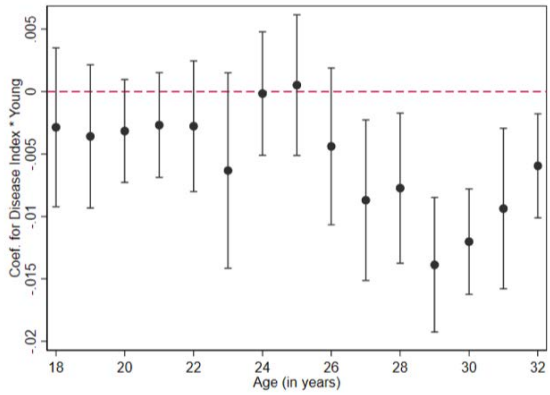
(a) Labor Force Participation



(b) Wage (conditional on employment)



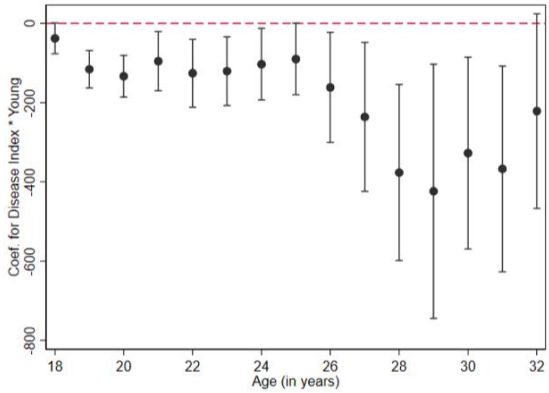
(c) Log Wage (conditional on employment)



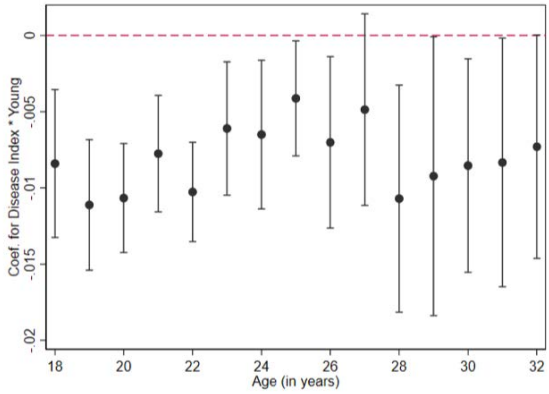
Notes: These figures plot the coefficients and 95% confidence intervals on the interaction term between the disease index and the younger sibling indicator from model (1), using outcomes measured at ages specified on the x-axes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effects, and family background controls. See notes under Table 2 for more details about the variables. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

Figure 6: Effects of the Respiratory Disease Exposure Index on Younger Siblings' Income, by Age of Observation

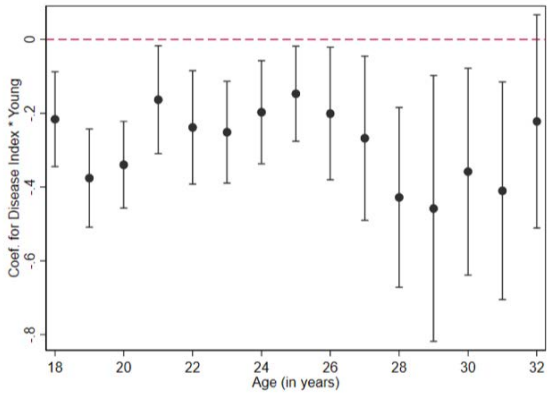
(a) Total Income (winsorized 1-99 pct)



(b) Log Total Income

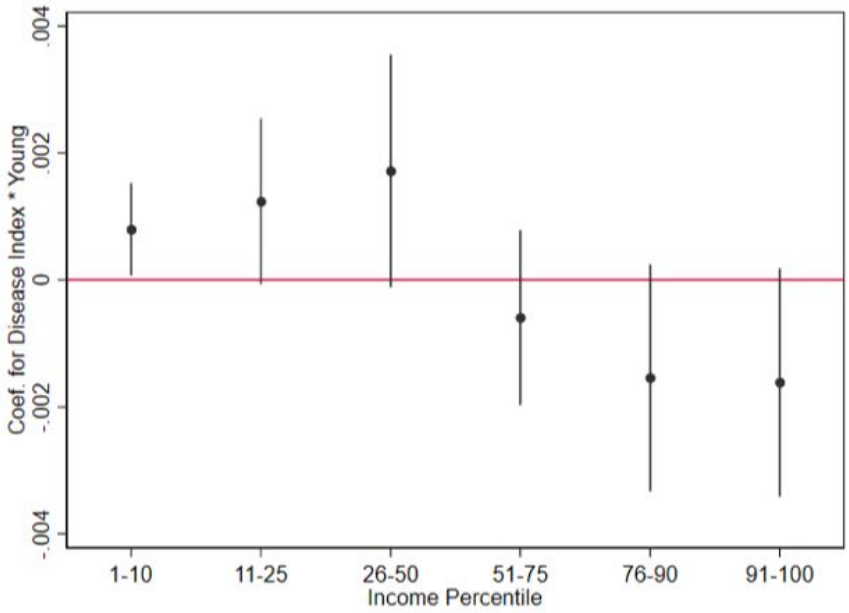


(c) Income Percentile



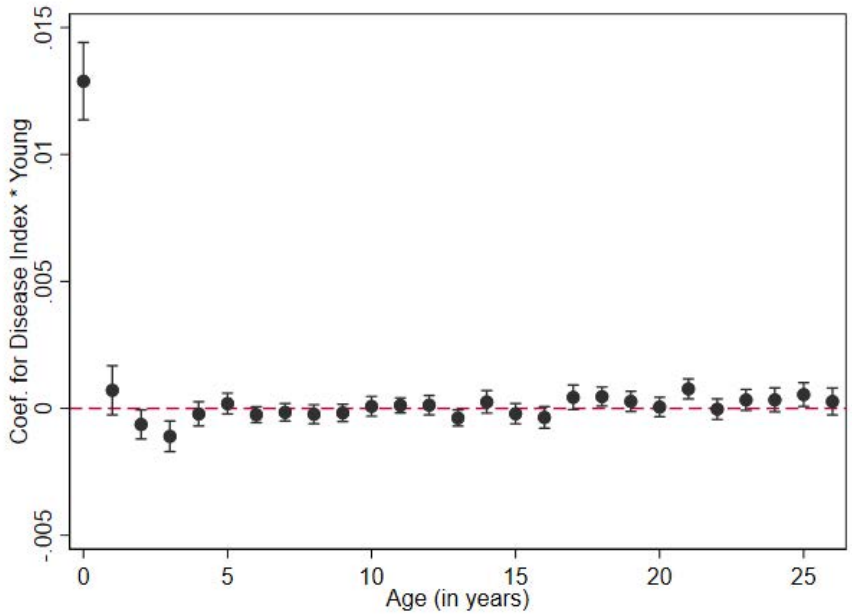
Notes: These figures plot the coefficients and 95% confidence intervals on the interaction term between the disease index and the younger sibling indicator from model (1), using outcomes measured at ages specified on the x-axes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effects, and family background controls. See notes under Table 2 for more details about the variables. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

Figure 7: Effects of the Respiratory Disease Exposure Index on Younger Siblings' Income Distribution



Notes: This figure plots the coefficients and 95% confidence intervals on the interaction term between the disease index and the younger sibling indicator from model (1) with age fixed effects. The sample includes sibling pairs at age 25-32, with each observation at person-by-age level. The outcome is an indicator for the income percentile falling into each percentile bin denoted on the x-axis among population of the same age in the same year. All regressions include municipality, year-month of birth, age fixed effects, and family background controls. Confidence intervals are constructed from two-way clustered standard errors at the individual and municipality of birth levels.

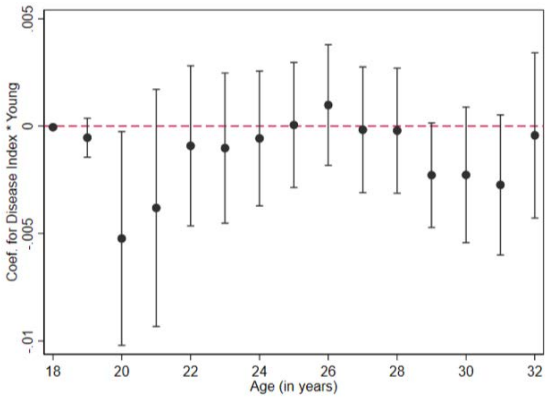
Figure 8: Effects of the Respiratory Disease Exposure Index on the Annual Number of Younger Siblings' Respiratory Hospitalizations, by Age of Observation



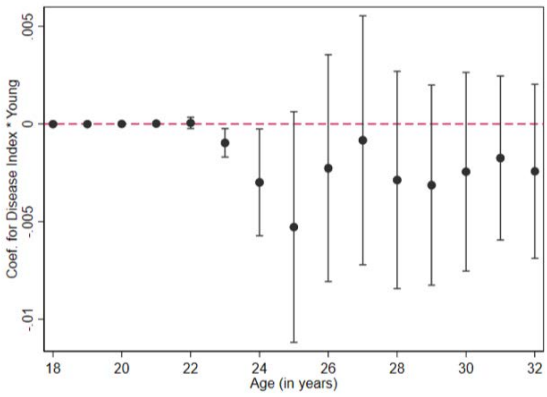
Notes: This figure plots the coefficients and 95% confidence intervals on the interaction term between the overall respiratory disease index and the younger sibling indicator from model (1), using as the outcome the annual number of hospitalizations with all respiratory diagnoses, measured at ages specified on the x-axis. The respiratory disease exposure index is the number of inpatient admissions with any respiratory disease primary diagnosis among children aged 13–71 months per 100 children in each child's municipality of birth during the first year of life, excluding any hospitalizations of an older sibling. All regressions include municipality, year-month of birth fixed effects, and family background controls, including indicator for child gender, the sibling pair's birth spacing (in months) and the birth spacing interacted with the indicator for the younger child, mother's age and age squared, indicator for the mother being foreign-born, indicators for mother's education level (high school degree, college degree or higher), and an indicator for the parents being married or cohabiting at the time of childbirth. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

Figure 9: Effects of the Respiratory Disease Exposure Index on Younger Siblings' Education Outcomes, by Age of Observation

(a) High School Graduation

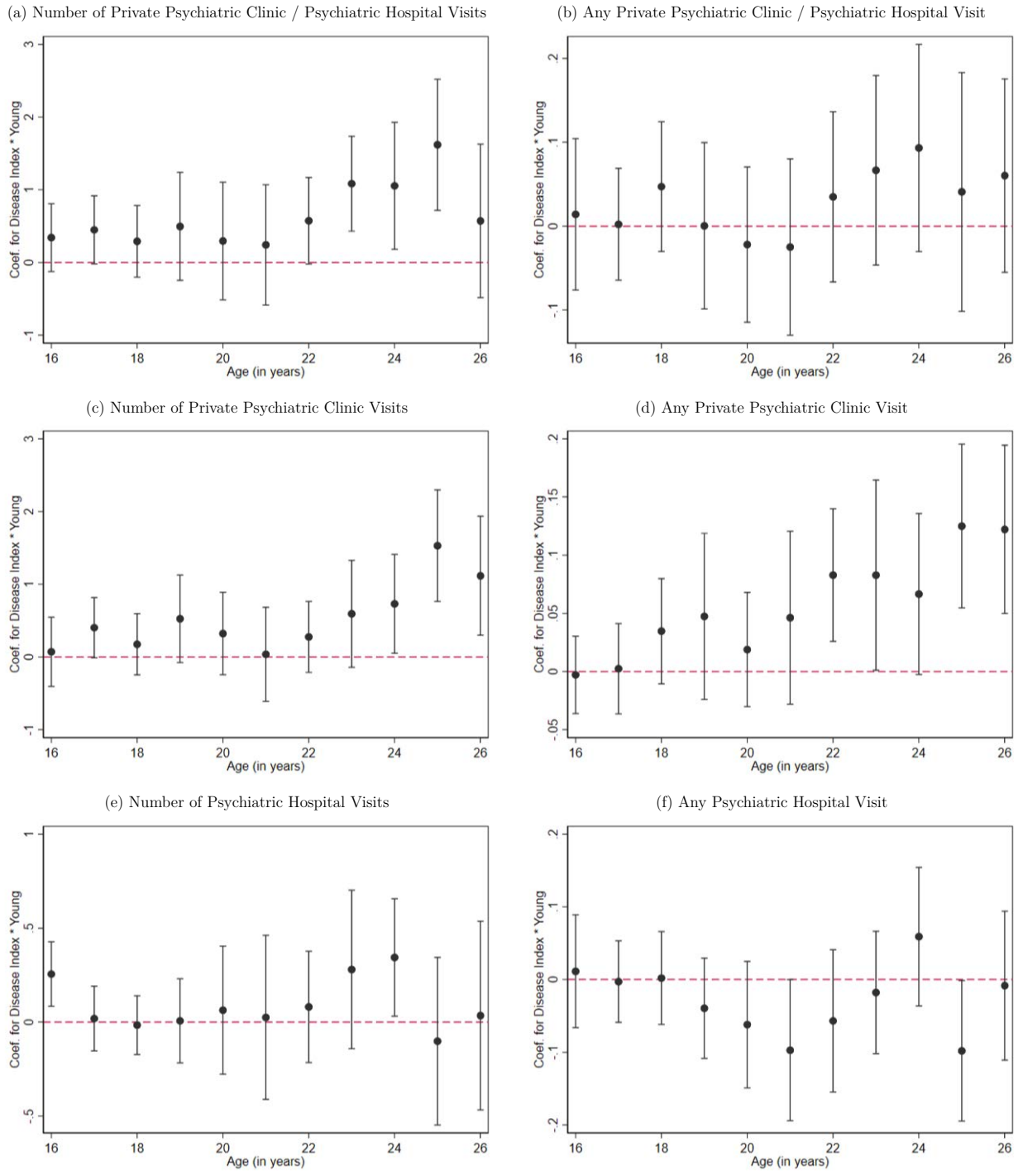


(b) College Graduation



Notes: These figures plot the coefficients and 95% confidence intervals on the interaction term between the disease index and the younger sibling indicator from model (1), using outcomes measured at ages specified on the x-axes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effects, and family background controls. See notes under Figure 8 for more details about the specifications and variables. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

Figure 10: Effects of the Respiratory Disease Exposure Index on Younger Siblings' Mental Health Care Outcomes, by Age of Observation



Notes: These figures plot the coefficients and 95% confidence intervals on the interaction term between the disease index and the younger sibling indicator from model (1), using the mental health care outcomes measured at ages specified on the x-axes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effects, and family background controls. See notes under Figure 8 for more details about the specifications and variables. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

8 Tables

Table 1: Variable Means

	Older Siblings	Younger Siblings
Disease Exposure Indices		
Respiratory Disease Exposure Index	2.801	2.895
Respiratory Disease Exposure Index (post-1993 cohorts)	3.023	3.036
RSV Exposure Index (post-1993 cohorts)	0.104	0.100
Child Characteristics		
Male Child	0.514	0.514
Birth Weight (grams)	3431.247	3589.977
Birth Spacing (months)	42.085	42.085
Family Background Characteristics		
Mother's Age at Childbirth	26.858	30.368
Mother is Foreign-Born	0.047	0.047
Mother has High School Degree	0.752	0.791
Mother has College Degree	0.309	0.374
Parents are Married/Cohabiting (Year after birth)	0.934	0.949
Log Household Income	11.441	11.616
*Respiratory Disease Hospitalizations by Age 1 (*100)*		
Number of Respiratory Disease Hospitalizations by Age 1	4.710	9.280
Number of Respiratory Disease Hospitalizations by Age 1 (post-1993 cohorts)	4.584	10.332
Number of RSV Hospitalizations by Age 1 (post-1993 cohorts)	0.876	2.816
Labor Market Outcomes		
In Labor Force, Age 25-32	0.654	0.651
Wage (conditional on employed), Age 25-32	54,447.628	55,077.517
Log Wage (conditional on employed), Age 25-32	10.800	10.812
Total Income (winsorized 1-99pct), Age 25-32	46,344.763	46,343.652
Log Total Income, Age 25-32	10.576	10.563
Income Percentile, Age 25-32	56.601	56.085
Educational Outcomes		
High School Degree, Age 30	0.848	0.838
College Degree, Age 30	0.446	0.426
Danish Test Score, Grade 9	0.150	0.047
Math Test Score, Grade 9	0.204	0.075
*Mental Health Outcomes, Ages 16-26 (*100)*		
Any Psychiatric Hospital / Psychiatrist Visit	3.091	3.827
Number of Psychiatric Hospital / Psychiatrist Visits	11.552	14.229
Any Psychiatric Hospital Visit	2.271	2.884
Number of Psychiatric Hospital Visits	4.582	5.856
Any Psychiatrist Visit	1.016	1.206
Number of Psychiatrist Visits	7.213	8.671
Observations	615,090	615,090

Notes: This table presents the means of key variables in our analysis separately for older and younger siblings. The respiratory disease exposure index is the number of inpatient admissions with a respiratory disease primary diagnosis among children aged 13–71 months per 100 children in the focal child's municipality of birth during the first year of life, excluding any hospitalizations of an older sibling. Average labor market outcomes are calculated from siblings pairs at age 25-32. At each age, we require both of the siblings are observed. Income is reported in 2010 $USD. Income percentile is calculated among each year-age group. Test scores are converted into $z-$scores, which are standardized within each subject and test year. Test score data are only available for children born in 1986–2003. Average long-term health outcomes are calculated from siblings pairs at age 15-25. At each age, we also require both of the siblings are observed. Maternal educational attainment and parental marital/cohabiting status are measured at the time of childbirth, while household income is measured in the year before childbirth.

Table 2: Effect of Respiratory Disease Exposure Index on Respiratory Disease Hospitalizations in First Year of Life, Younger versus Older Siblings

	All Respiratory Hospitalizations in First Year of Life				
	(1)	(2)	(3)	(4)	(5)
Younger	0.041***		0.041***	0.006***	0.042***
	(0.002)		(0.002)	(0.002)	(0.003)
Disease index		0.018***	0.018***	0.011***	0.011***
		(0.001)	(0.001)	(0.001)	(0.001)
Younger x disease index				0.012***	0.013***
				(0.001)	(0.001)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	No	No	No	No	Yes
Observations	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180
Mean	0.070	0.070	0.070	0.070	0.070
25th to 75th pctile effect size				0.023	0.024

Notes: Each column in the table presents results from estimating different versions of model (1). The outcome is the number of hospitalizations with any respiratory disease primary diagnosis during the first year of the child's life. We report the coefficients on the indicator variable denoting the younger sibling ("Younger"), the respiratory disease exposure index ("Disease index"), and the interaction of these two variables. The respiratory disease exposure index is the number of inpatient admissions with any respiratory disease primary diagnosis among children aged 13–71 months per 100 children in each child's municipality of birth during the first year of life, excluding any hospitalizations of an older sibling. All specifications include municipality, year-month of birth fixed effects. Column (5) also includes the following family background controls: indicator for child gender, the sibling pair's birth spacing (in months) and the birth spacing interacted with the indicator for the younger child, mother's age and age squared, indicator for the mother being foreign-born, indicators for mother's education level (high school degree, college degree or higher), and an indicator for the parents being married or cohabiting at the time of childbirth. Standard errors are clustered on the child's municipality of birth in all models. The "25th to 75th pctile effect size" row reports the magnitude of the differential effect of an increase in the disease exposure index from the 25th to the 75th percentile of the distribution for younger siblings. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table 3: Effect of Respiratory Disease Exposure Index in First Year of Life on Labor Market Participation and Wage at Ages 25–32, Younger versus Older Siblings

	(1)	(2)	(3)	(4)	(5)	(6)
	Labor Market Participation		Wage (cond. on emp.)		Log Wage (cond. on emp.)	
Younger	-0.014***	-0.012***	-1,228.410***	-703.461***	-0.024***	-0.011**
	(0.002)	(0.003)	(173.180)	(252.761)	(0.003)	(0.005)
Disease index		0.005***		112.481		0.002
		(0.002)		(105.634)		(0.002)
Younger x disease index		-0.001		-235.420***		-0.006***
		(0.001)		(79.905)		(0.002)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,377,733	2,377,733	1,616,792	1,616,792	1,612,736	1,612,736
Mean	0.698	0.698	57,067.833	57,067.833	10.856	10.856
25th to 75th pctile effect size		-0.002		-330.707		-0.008

Notes: See notes under Table 2 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table 4: Effect of Respiratory Disease Exposure Index in First Year of Life on Income at Ages 25–32, Younger versus Older Siblings

	(1)	(2)	(3)	(4)	(5)	(6)
	Total Income(winsorized)		Log Total Income		Income Percentile	
Younger	1,091.327***	-651.411***	-0.023***	-0.008	1.303***	-0.759***
	(135.037)	(176.874)	(0.004)	(0.005)	(0.166)	(0.209)
Disease index		210.312**		0.005*		0.288**
		(101.336)		(0.003)		(0.124)
Younger x disease index		-192.866**		-0.006***		-0.238***
		(73.955)		(0.002)		(0.090)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,377,733	2,377,733	2,372,145	2,372,145	2,377,726	2,377,726
Mean	49,345.560	49,345.560	10.652	10.652	56.566	56.566
25th to 75th pctile effect size		-276.802		-0.009		-0.342

Notes: See notes under Table 2 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

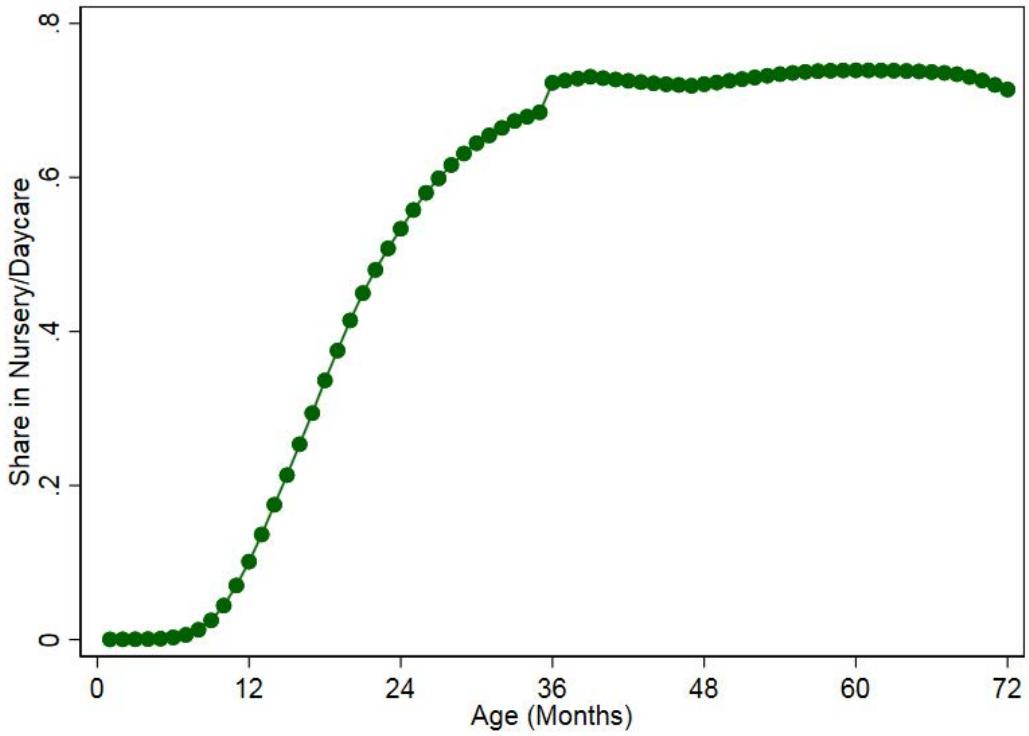
Table 5: Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Mental Health Outcomes at Ages 16-26

	(1)	(2)	(3)	(4)	(5)	(6)
	Number of Visits	Any Visit	Number of Clinic Visits	Any Clinic Visit	Number of Hospital Visits	Any Hospital Visit
Younger	-1.071**	0.051	-1.281***	-0.103***	0.162	0.151**
	(0.508)	(0.090)	(0.402)	(0.037)	(0.253)	(0.076)
Disease index	-0.121	0.040	-0.282	-0.030	0.119	0.061**
	(0.235)	(0.037)	(0.200)	(0.020)	(0.082)	(0.026)
Younger x disease index	0.346**	0.008	0.289**	0.032***	0.051	-0.024
	(0.151)	(0.023)	(0.119)	(0.011)	(0.084)	(0.019)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,067,930	6,067,930	6,488,017	6,488,017	6,067,930	6,067,930
Mean	13.623	3.490	8.585	1.213	5.299	2.535
25th to 75th pctile effect size	0.556	0.013	0.472	0.053	0.083	-0.038

Notes: See notes under Table 2 for more details about the specifications and variables. The sample includes sibling pairs at ages 16-26, with each observation at the person-by-age level. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

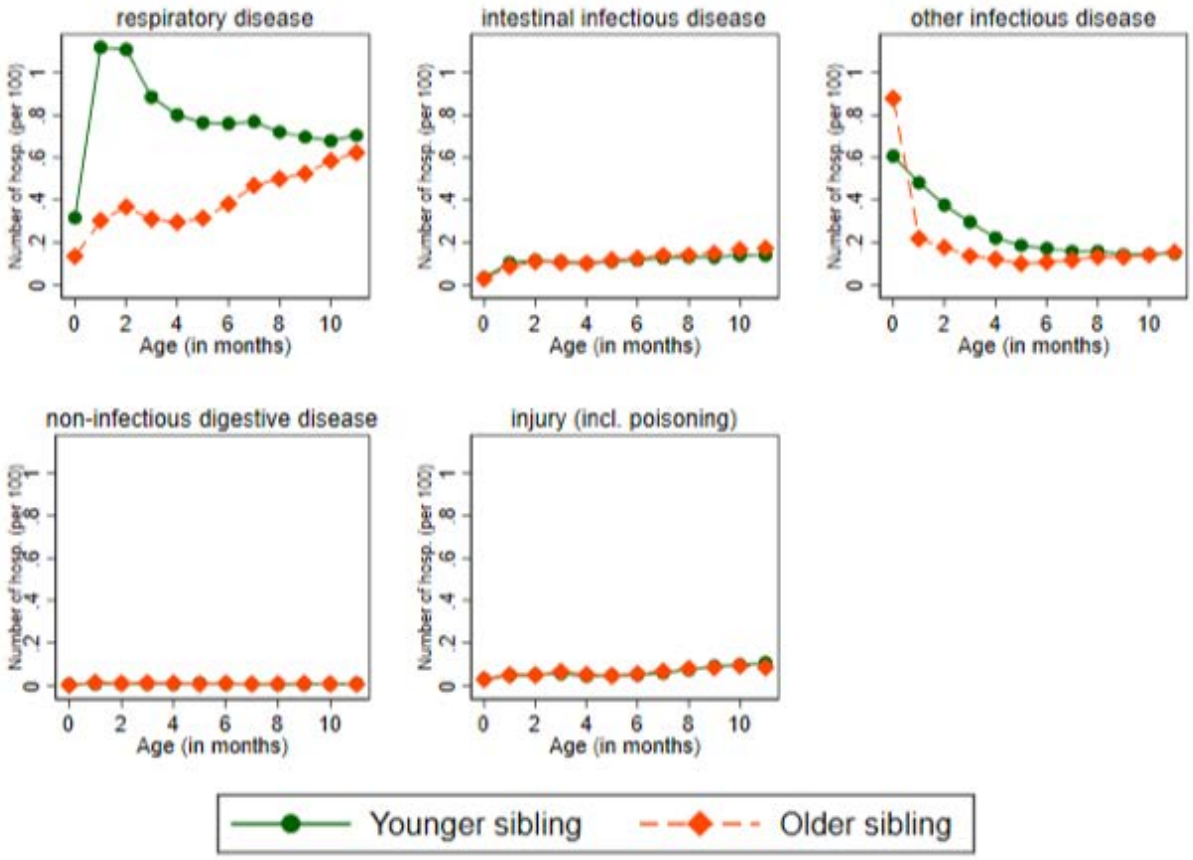
A Appendix Figures

Figure A1: Share of Children Attending Group Childcare by Child Age in Months



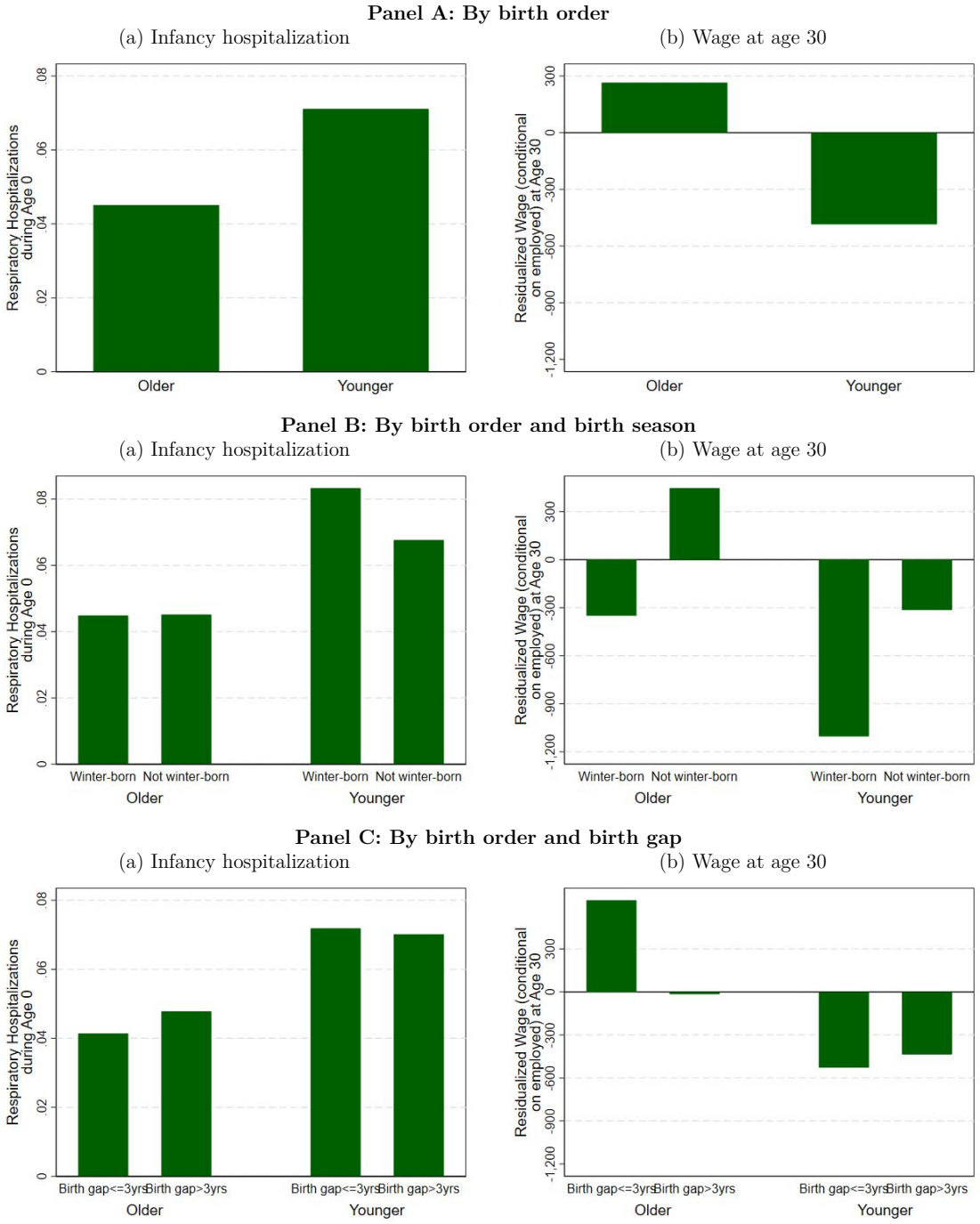
Notes: This graph shows the share of children who are attending childcare by age in months. We use data on enrollment in Danish childcare centers, which is reported annually in September of each year. This information is available to us over the period of September 1995 to September 2013.

Figure A2: Number of Hospitalizations per 100 Children, by Disease Type, Child Age in Months, Older versus Younger Siblings



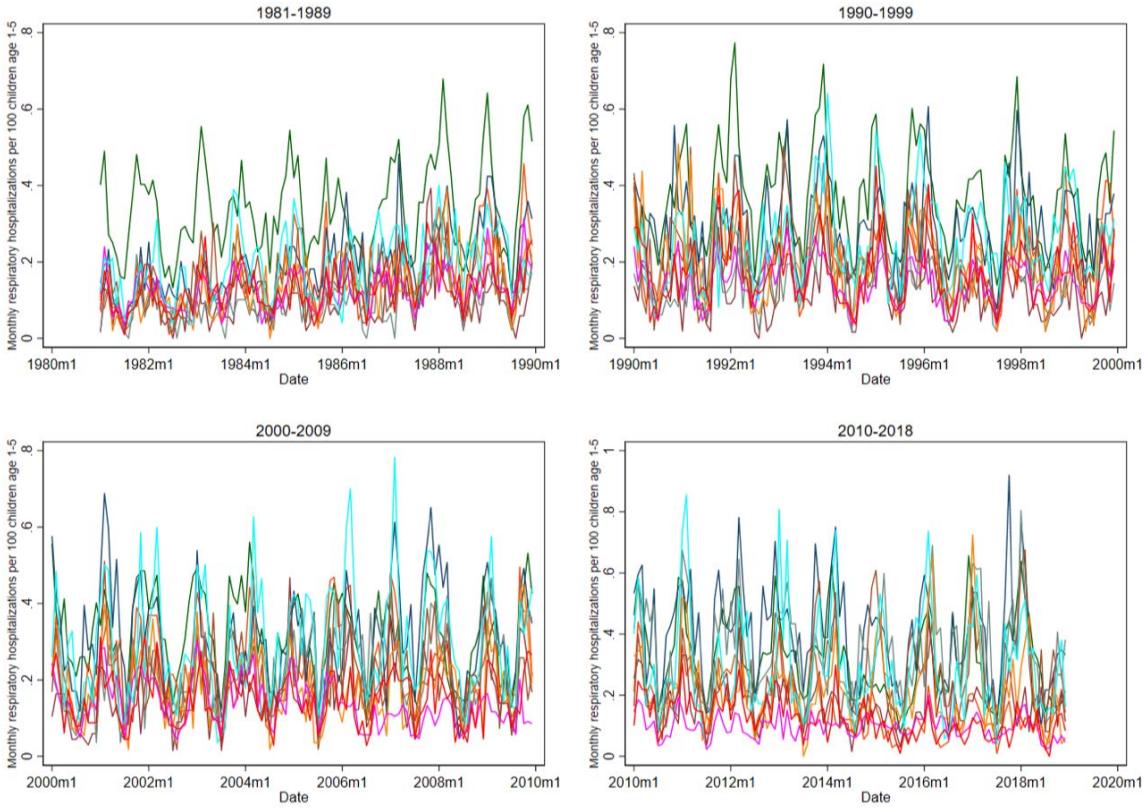
Notes: These figures plot the number of hospitalizations with different types of diagnoses (per 100 children) by month of age, separately for older and younger siblings in our data. Respiratory diseases are identified using ICD-8 code starting with "46", "47", "48", "490", "079", "783", and ICD-10 code starting with "J" (excluding "J4") or "B974". Intestinal infectious diseases include ICD-8 codes starting with "00" and ICD-10 codes starting with "A0". Other infectious diseases include ICD-8 codes starting with "0" (excluding "00" and "079"), "10", "11", "12", "13", "320", "323", "710", and ICD-10 codes starting with "A" (excluding "A0"), "B" (excluding "B974"), "G00"-"G05", "M00"-"M02", "P23", "P35"-"P37". Due to lack of corresponding codes in ICD-8, non-infectious digestive diseases are only identified using ICD-10 codes starting with "K50"–"K52", and injury (including poisoning) hospitalizations are identified using ICD-10 codes starting with "S" or "T". For these two types of conditions, hospitalization rates are calculated using cohorts born in or after 1993 when the diagnosis system switched to ICD-10 version.

Figure A3: Respiratory Hospitalizations during First Year of Life and Residualized Wage at Age 30



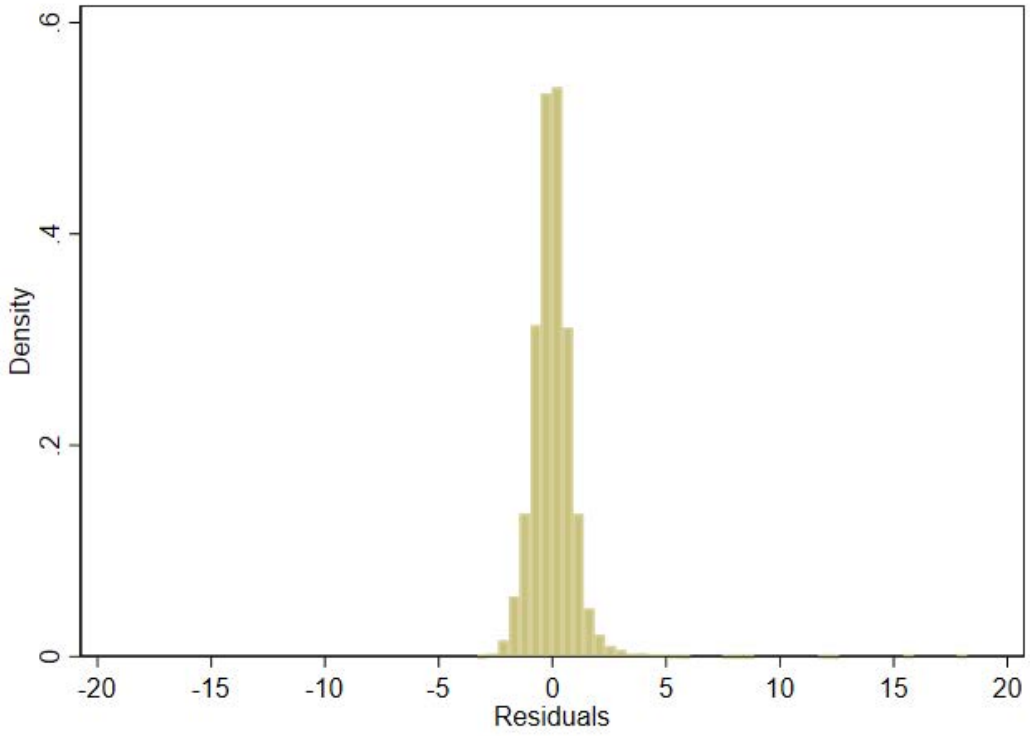
Notes: These figures plot the number of hospitalizations with respiratory illness diagnoses during age 0 and residualized wage income (conditional on employment) at age 30, by birth order, birth season, and birth gap. The sample includes first- and second-born sibling pairs born from 1981 to 1989. Wage income is measured at age 30 and residualized after controlling for year fixed effect. "Winter-born" refers to children born in November, December, and January.

Figure A4: Variation in the Respiratory Disease Index Over Time, 10 Largest Municipalities



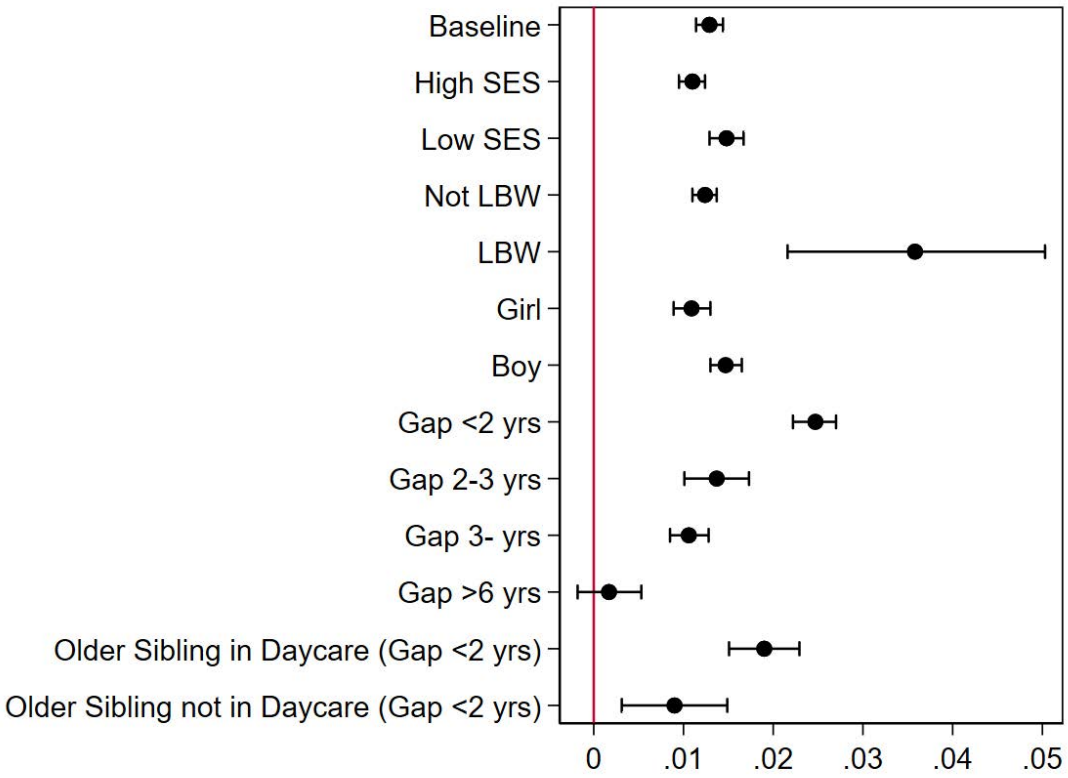
Notes: This figure shows the monthly variation in the respiratory disease index over time for each of the 10 largest municipalities (in terms of population size) in Denmark, separately for time periods of 1981-1989, 1990-1999, 2000-2009, and 2010-2018. The respiratory disease index refers to the number of respiratory disease hospitalizations per 100 children aged 13 to 71 months in each calendar year-month.

Figure A5: Distribution of Respiratory Disease Index Residuals from Municipality and Year-Month Fixed Effects



Notes: This histogram plots the residuals after regressing the respiratory disease index on municipality and year-month fixed effects. The respiratory disease index refers to the number of respiratory disease hospitalizations per 100 children aged 13 to 71 months in each calendar year-month.

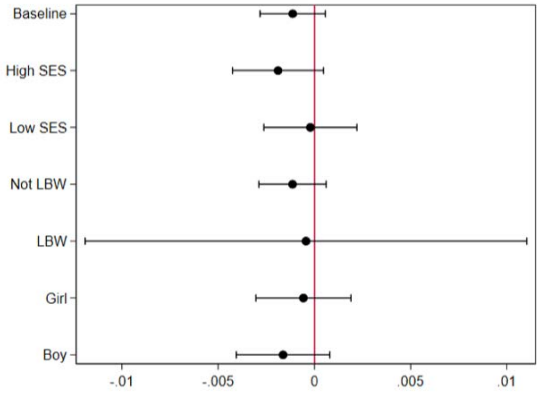
Figure A6: Heterogeneous Effects of the Respiratory Disease Exposure Index on the Annual Number of Younger Siblings' Respiratory Hospitalizations



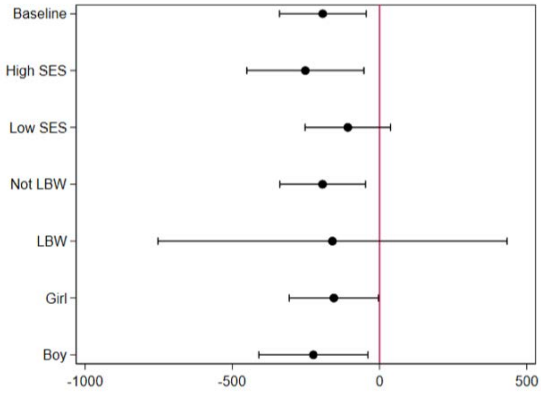
Notes: This figure plots the heterogeneity effects of the respiratory disease exposure on younger siblings respiratory hospitalizations among different sub-populations. The baseline coefficient and 95% confidence intervals are from the interaction term between the overall respiratory disease index and the younger sibling indicator from model (1). The respiratory disease exposure index is the number of inpatient admissions with any respiratory disease primary diagnosis among children aged 13-71 months per 100 children in each child's municipality of birth during the first year of life, excluding any hospitalizations of an older sibling. Effects by sub-groups are from 5 separate regressions: 1) high vs. low socioeconomic status (SES), grouped based on the mother's education level in the year of birth being above or below the median level among mothers in the same year; 2) low birth weight (LBW) status; 3) child gender; 4) birth spacing; and 5) whether the older child is in a childcare center during the first year of life of the younger child, restricting to sibling pairs born within 2 years of each other, and between September 1995 and September 2013 (the period of time covered by our childcare enrollment data). In each regression, the full set of sub-group indicators are interacted with the younger sibling indicator, the disease index, and the younger sibling indicator x disease index interaction. Coefficients and 95% confidence intervals of the triple interaction term are plotted accordingly. All regressions include municipality, year of birth, month of birth fixed effects, and family background controls, including indicator for child gender, the sibling pair's birth spacing (in months) and the birth spacing interacted with the indicator for the younger child, mother's age and age squared, indicator for the mother being foreign-born, indicators for mother's education level (high school degree, college degree or higher), and an indicator for the parents being married or cohabiting at the time of childbirth. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

Figure A7: Heterogeneous Effects of the Respiratory Disease Exposure Index on Younger Siblings' Labor Market Outcomes

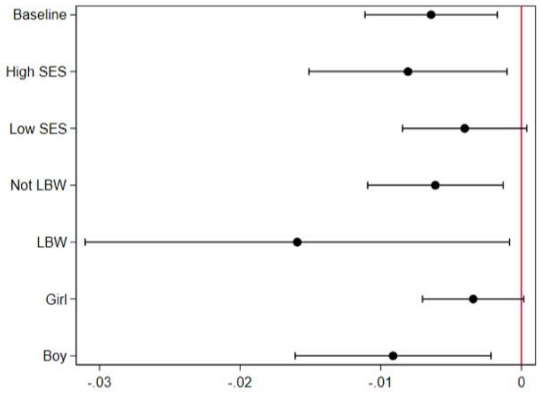
(a) Labor Force Participation



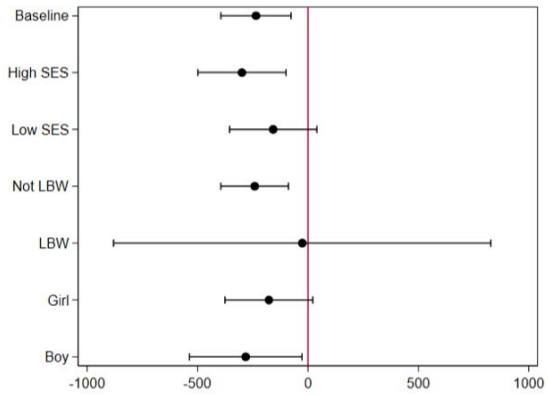
(b) Total Income (winsorized 1-99 pct)



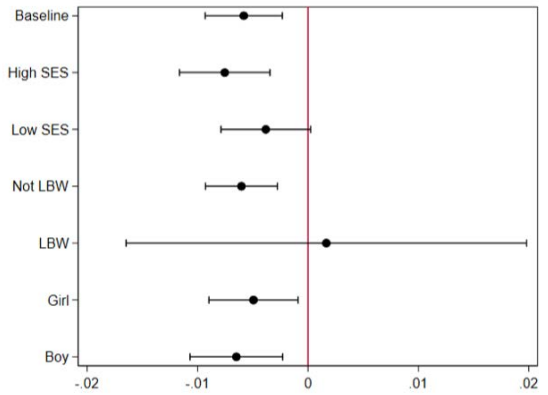
(c) Log Total Income



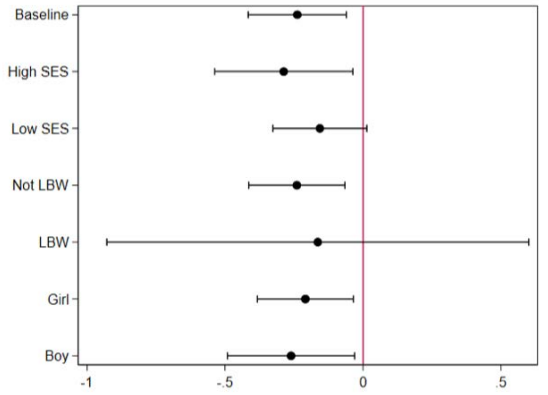
(d) Wage (conditional on employment)



(e) Log Wage (conditional on employment)



(f) Income Percentile



Notes: These figures plot the heterogeneity effects of the respiratory disease exposure on younger siblings labor market outcomes among different sub-populations. The baseline coefficient and 95% confidence intervals are from the interaction term between the overall respiratory disease index and the younger sibling indicator from model (1). Effects by subgroups are from 3 separate regressions: 1) high vs. low socioeconomic status (SES); 2) low birth weight (LBW) status; and 3) child gender. In each regression, the full set of sub-group indicators are interacted with the younger sibling indicator, the disease index, and the younger sibling indicator × disease index interaction. Coefficients and 95% confidence intervals of the triple interaction term are plotted accordingly. All regressions include municipality, year-month of birth fixed effects, and family background controls. See notes under Appendix Figure A6 for more details about the definition of each subgroups and variables used in the specification. Confidence intervals are constructed from standard errors clustered on the child's municipality of birth.

B Appendix Tables

Table A1: Sample Construction Process

Sample Restriction	Observations
Birth cohort 1981-2015	2,278,868
Singleton first and second-born	1,409,984
Birth spacing gap at least 11 months	1,406,506
Drop sibling pairs with missing municipality of birth information, or born in municipalities with less than 1,000 children aged 13-71 months on average	1,368,208
Drop sibling pairs with missing parental control variables	1,230,180

Notes: This table shows how our sample size changes as we make various restrictions to arrive at our final analysis sample.

Table A2: Disease Exposure Index and Family Background Characteristics

	(1) Male	(2) LBW	(3) VLBW	(4) Mother's Age	(5) Mother Foreign-Born	(6) Mother HS Graduated	(7) Mother College Graduated	(8) Parents Married /Cohabiting	(9) Father Log Income	(10) Mother Log Income	(11) Household Log Income	(12) Father Employed	(13) Mother Employed
Younger	-.00131	-.0173***	-.0023***	2.79***	-.00666*	.00958	.0387***	.0165***	.136***	.165***	.132***	.0512***	.0149
	(.0028)	(.00111)	(.000272)	(.044)	(.00381)	(.00852)	(.00552)	(.00383)	(.0256)	(.0172)	(.0194)	(.0145)	(.0154)
Disease index	-.00152*	-.000318	-.000119	-.154***	.000231	.00065	-.0172***	-.00268*	-.0174***	-.014***	-.0157***	-.00802***	-.00348
	(.000833)	(.000336)	(.000124)	(.0348)	(.00143)	(.00197)	(.00627)	(.00147)	(.00472)	(.00306)	(.00411)	(.00271)	(.0026)
Younger x disease index	.000197	.000629	.000126	.122***	.000643	-.000587	.00237*	-.0025*	.00591	.00602	.00521	-.00131	-.000434
	(.000929)	(.000417)	(.0000947)	(.0298)	(.00189)	(.004)	(.00121)	(.00135)	(.00664)	(.00554)	(.0051)	(.00373)	(.00402)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180
Mean	0.514	0.033	0.004	28.613	0.047	0.771	0.342	0.942	10.914	10.622	11.529	0.869	0.753
25th to 75th pctile effect size	0.000	0.001	0.000	0.226	0.001	-0.001	0.004	-0.005	0.011	0.011	0.010	-0.002	-0.001

Notes: Each column in the table presents results from estimating model (1), separately for each of the dependent variables listed at the top. We report the coefficients on the indicator variable denoting the younger sibling ("Younger"), the respiratory disease exposure index ("Disease index"), and the interaction of these two variables. The disease exposure index is the number of inpatient admissions with a respiratory disease primary diagnosis among children aged 13–71 months per 100 children in each child's municipality of birth during the first year of life, excluding any hospitalizations of an older sibling. See notes under Table 2 for more details about the specifications. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A3: Effect of Non-Infectious Digestive Disease Exposure Index on Non-Infectious Digestive Disease Hospitalizations in First Year of Life, Younger versus Older Siblings

	Non-infectious Digestive Disease Hospitalizations in First Year of Life (*1000)				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.271***		-0.270***	-0.157	-0.052
	(0.102)		(0.102)	(0.110)	(0.190)
Non-infectious digestive disease index		2.190**	2.181**	3.406**	3.442**
		(1.057)	(1.056)	(1.622)	(1.637)
Younger x Non-infectious disease index				-2.196	-2.214
				(1.922)	(1.915)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	No	No	No	No	Yes
Observations	752,232	752,232	752,232	752,232	752,232
Mean	1.083	1.083	1.083	1.083	1.083
25th to 75th pctile effect size				-0.146	-0.148

Notes: See notes under Table 2 for more details about the specifications and variables. The outcome is the number of hospitalizations with any non-infectious digestive disease primary diagnosis during the first year of the child's life (only available for children born after 1993). Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A4: Effect of Injury (incl. Poisoning) Exposure Index on Injury (incl. Poisoning) Hospitalizations in First Year of Life, Younger versus Older Siblings

	Injury (incl. Poisonings) Hospitalizations in First Year of Life (*1000)				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.258		-0.271	-1.415	-0.319
	(0.255)		(0.256)	(1.010)	(1.131)
Injury index		3.987***	3.990***	3.432***	3.347***
		(0.563)	(0.563)	(0.743)	(0.745)
Younger x injury index				0.990	1.040
				(0.944)	(0.955)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	No	No	No	No	Yes
Observations	752,232	752,232	752,232	752,232	752,232
Mean	7.550	7.550	7.550	7.550	7.550
25th to 75th pctile effect size				0.399	0.419

Notes: See notes under Table 2 for more details about the specifications and variables. The outcome is the number of hospitalizations with any injury (incl. poisoning) primary diagnosis during the first year of the child's life (only available for children born after 1993). Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A5: Disease Exposure Index and Fertility Choice

	(1) Having 2nd Child	(2) Birth Spacing	(3) 2nd Child Born in 11/12/1	(4) 2nd Child Born in 2/3/4	(5) 2nd Child Born in 5/6/7	(6) 2nd Child Born in 8/9/10
Disease index	-.00704**	-.0494	.000601	-.000624	.000403	-.000379
	(.00306)	(.0761)	(.000889)	(.000913)	(.000908)	(.000802)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	886,603	671,615	671,615	671,615	671,615	671,615
Mean	0.758	51.787	0.231	0.249	0.263	0.256

Notes: This table presents the correlation between the disease exposure faced by the first child and family's decision on whether and when to have a second child. The full sample is constructed by all first-born child during years 1981-2016. The disease exposure index is the number of inpatient admissions with a respiratory disease primary diagnosis among children aged 13–71 months per 100 children in each child's municipality of birth during the first year of life. Outcome variable used in column (1) is an indicator for the same mother having another child during the sample period. Conditional on having another child, column (2) uses the birth spacing (in months) between the first- and second-born as the outcome variable, and columns (3)-(6) use indicators for the birth season of the second-born as outcome variables. All regressions include municipality, year-month of birth fixed effect, and family background controls, same as listed in Table 2 except excluding birth spacing and birth spacing interacted with the indicator for the younger child. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A6: Effect of RSV Index on RSV Hospitalizations in the First Year of Life, Younger versus Older Siblings

	RSV Hospitalizations in First Year of Life				
	(1)	(2)	(3)	(4)	(5)
Younger	0.019***		0.019***	0.014***	0.029***
	(0.001)		(0.001)	(0.001)	(0.001)
RSV index		0.042***	0.042***	0.017***	0.018***
		(0.004)	(0.004)	(0.003)	(0.003)
Younger x RSV index				0.048***	0.045***
				(0.004)	(0.004)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	No	No	No	No	Yes
Observations	752,232	752,232	752,232	752,232	752,232
Mean	0.018	0.018	0.018	0.018	0.018
25th to 75th pctile effect size				0.005	0.005

Notes: See notes under Table 2 for more details about the specifications and variables. The outcome is the number of hospitalizations with an RSV primary diagnosis during the first year of the child's life (only available for children born after 1993). The disease index is constructed using hospitalizations for RSV only (rather than all hospitalizations for respiratory conditions). Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A7: Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Labor Force Participation and Wage, by Age of Observation

	(1) Age 18	(2) Age 19	(3) Age 20	(4) Age 21	(5) Age 22	(6) Age 23	(7) Age 24	(8) Age 25	(9) Age 26	(10) Age 27	(11) Age 28	(12) Age 29	(13) Age 30	(14) Age 31	(15) Age 32
Panel A: Labor Force Participation															
Younger	0.023***	0.032***	0.045***	0.045***	0.041***	0.035***	0.029***	0.022***	0.009*	0.003	0.009**	0.005	-0.002	-0.007	-0.002
	(0.003)	(0.003)	(0.004)	(0.005)	(0.008)	(0.007)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.009)	(0.007)	(0.008)
Disease index	-0.002	-0.003	-0.003*	-0.006***	-0.004	0.000	0.002	0.001	0.003	0.002	0.002	0.003	0.002	0.000	0.009**
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Younger x disease index	0.000	0.001	0.002	0.003	0.003	0.001	0.000	0.001	0.001	0.000	-0.002	-0.002	-0.002	0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	639,640	600,958	560,010	519,190	478,768	438,168	399,012	357,380	315,556	275,884	234,640	197,428	161,932	128,072	96,620
Mean	0.130	0.223	0.402	0.494	0.461	0.460	0.491	0.544	0.613	0.682	0.738	0.778	0.808	0.829	0.842
25th to 75th pctile effect size	0.001	0.003	0.004	0.008	0.007	0.003	0.001	0.002	0.003	0.001	-0.005	-0.005	-0.003	0.002	-0.001
Panel B: Wage (conditional on employment)															
Younger	419.529	1,080.467***	746.578***	569.126**	763.479**	757.330*	-170.144	-101.441	275.884	881.983**	815.769	114.519	33.362	45.209	1,144.952
	(303.999)	(291.620)	(186.430)	(230.312)	(317.664)	(429.334)	(368.438)	(348.204)	(421.427)	(427.458)	(530.072)	(524.883)	(500.902)	(703.202)	(717.771)
Disease index	85.471	88.968	218.585***	245.775**	266.323**	232.351	135.162	-69.653	22.722	161.531	172.489	137.219	158.057	476.410	321.744
	(122.296)	(110.519)	(82.482)	(96.861)	(126.859)	(145.712)	(149.923)	(133.721)	(152.597)	(167.666)	(211.380)	(217.163)	(283.552)	(320.864)	(350.991)
Younger x disease index	-32.348	-75.186	-79.264	-111.991	-166.733*	-100.371	52.892	-44.145	-267.940**	-467.233***	-438.551***	-613.158***	-512.891***	-516.368**	-489.650***
	(82.576)	(99.364)	(81.631)	(82.557)	(97.035)	(162.119)	(116.038)	(95.580)	(106.755)	(105.720)	(141.286)	(162.246)	(178.043)	(245.990)	(177.532)
Observations	21,286	45,920	106,684	142,762	117,884	108,348	110,310	115,366	123,702	129,606	127,150	118,344	104,176	86,112	67,126
Mean	24,313.995	28,977.891	31,964.308	35,381.597	39,948.179	43,589.128	46,339.506	49,069.745	52,092.185	54,975.771	57,743.520	60,216.139	62,432.581	64,876.528	67,228.447
25th to 75th pctile effect size	-76.002	-177.978	-190.890	-261.823	-390.415	-236.653	125.973	-103.638	-619.656	-1,029.368	-949.648	-1,268.661	-1,045.451	-1,012.330	-930.408
Panel C: Log Wage (conditional on employed)															
Younger	0.023*	0.043***	0.024***	0.014**	0.014	0.024**	-0.002	-0.011	0.006	0.014	0.013	0.002	0.007	0.010	0.008
	(0.013)	(0.011)	(0.007)	(0.006)	(0.009)	(0.010)	(0.008)	(0.009)	(0.011)	(0.011)	(0.011)	(0.009)	(0.009)	(0.010)	(0.010)
Disease index	0.006	0.002	0.007**	0.006**	0.008**	0.010***	0.004	-0.002	0.001	0.001	0.003	0.005	0.006	0.010**	0.004
	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)
Younger x disease index	-0.003	-0.004	-0.003	-0.003	-0.003	-0.006	-0.000	0.001	-0.004	-0.009***	-0.008**	-0.014***	-0.012***	-0.009***	-0.006***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
Observations	21,260	45,834	106,540	142,502	117,576	107,960	109,854	114,828	123,116	128,918	126,526	117,754	103,674	85,652	66,794
Mean	10.047	10.217	10.307	10.395	10.505	10.587	10.649	10.711	10.774	10.831	10.881	10.923	10.959	10.994	11.028
25th to 75th pctile effect size	-0.007	-0.008	-0.008	-0.006	-0.006	-0.015	-0.000	0.001	-0.010	-0.019	-0.017	-0.029	-0.024	-0.018	-0.011

Notes: These table presents the regression results from model (1), using labor market outcomes measured at each age between 18 to 32 as outcomes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A8: Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Income, by Age of Observation

	(1) Age 18	(2) Age 19	(3) Age 20	(4) Age 21	(5) Age 22	(6) Age 23	(7) Age 24	(8) Age 25	(9) Age 26	(10) Age 27	(11) Age 28	(12) Age 29	(13) Age 30	(14) Age 31	(15) Age 32
Panel A: Total Income (winsorized 1-99pct)															
Younger	908.039***	1,291.414***	1,326.492***	1,181.590***	1,279.825***	1,221.498***	1,035.317***	750.662***	694.413***	640.171**	653.189*	442.463	196.661	-18.018	142.220
	(70.005)	(84.154)	(108.169)	(123.193)	(143.132)	(153.528)	(182.882)	(163.909)	(205.882)	(272.702)	(336.673)	(408.266)	(438.789)	(413.182)	(496.111)
Disease index	-0.700	78.006	119.630*	58.223	74.125	154.058**	96.525	45.650	213.323**	182.262	264.274**	313.709*	118.375	209.176	254.081
	(37.859)	(58.120)	(60.734)	(61.022)	(69.571)	(75.309)	(81.800)	(100.208)	(95.593)	(123.066)	(131.022)	(175.794)	(190.224)	(191.245)	(241.434)
Younger x disease index	-37.721*	-115.622***	-133.269***	-95.218**	-125.807***	-120.439***	-102.798**	-89.774*	-161.460**	-235.898**	-376.368***	-423.518**	-327.232***	-366.991***	-221.159*
	(19.440)	(23.754)	(26.475)	(37.526)	(43.104)	(43.555)	(45.450)	(45.331)	(69.923)	(94.656)	(111.769)	(161.511)	(121.826)	(130.692)	(123.657)
Observations	639,640	600,958	560,010	519,190	478,768	438,168	399,012	357,380	315,556	275,884	234,640	197,428	161,932	128,072	96,620
Mean	9,949.178	16,406.034	22,525.501	27,212.332	29,917.630	32,474.254	35,241.664	38,736.892	42,940.125	47,071.616	50,915.826	54,254.167	57,102.613	59,720.155	61,930.460
25th to 75th pctile effect size	-93.175	-283.538	-326.744	-232.175	-306.217	-291.535	-249.707	-213.161	-377.073	-525.809	-822.382	-884.489	-671.085	-723.449	-421.715
Panel B: Log Total Income															
Younger	0.117***	0.087***	0.077***	0.054***	0.055***	0.043***	0.039***	0.028***	0.033***	0.024**	0.021*	0.022**	0.017	0.006	0.010
	(0.010)	(0.008)	(0.007)	(0.006)	(0.006)	(0.007)	(0.008)	(0.006)	(0.008)	(0.010)	(0.012)	(0.011)	(0.012)	(0.015)	(0.014)
Disease index	0.007	0.011**	0.010***	0.007**	0.007**	0.008***	0.007**	0.003	0.009**	0.002	0.007*	0.006	0.001	0.003	0.012
	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.007)
Younger x disease index	-0.008***	-0.011***	-0.011***	-0.008***	-0.010***	-0.006***	-0.006***	-0.004**	-0.007**	-0.005	-0.011***	-0.009**	-0.009**	-0.008**	-0.007*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)
Observations	637,264	599,874	558,756	517,862	477,416	436,628	397,458	355,900	314,172	274,560	233,500	196,446	161,138	127,414	96,128
Mean	8.797	9.461	9.814	10.023	10.128	10.220	10.304	10.404	10.513	10.609	10.696	10.770	10.833	10.892	10.938
25th to 75th pctile effect size	-0.021	-0.027	-0.026	-0.019	-0.025	-0.015	-0.016	-0.010	-0.016	-0.011	-0.023	-0.019	-0.017	-0.016	-0.014
Panel C: Income Percentile															
Younger	3.468***	3.601***	3.130***	2.285***	2.324***	2.162***	1.751***	1.315***	1.079***	0.834**	0.707*	0.268	0.077	-0.130	0.124
	(0.233)	(0.240)	(0.233)	(0.235)	(0.242)	(0.245)	(0.281)	(0.226)	(0.250)	(0.324)	(0.366)	(0.452)	(0.495)	(0.479)	(0.563)
Disease index	0.143	0.283*	0.292**	0.055	0.071	0.264**	0.176	0.054	0.278**	0.196	0.272*	0.360*	0.120	0.238	0.270
	(0.136)	(0.160)	(0.132)	(0.115)	(0.113)	(0.120)	(0.122)	(0.133)	(0.124)	(0.146)	(0.156)	(0.198)	(0.213)	(0.217)	(0.280)
Younger x disease index	-0.216***	-0.376***	-0.340***	-0.163**	-0.239***	-0.251***	-0.197***	-0.147**	-0.201**	-0.268**	-0.428***	-0.458**	-0.358**	-0.410***	-0.222
	(0.065)	(0.067)	(0.059)	(0.074)	(0.077)	(0.069)	(0.070)	(0.065)	(0.090)	(0.112)	(0.123)	(0.181)	(0.141)	(0.148)	(0.146)
Observations	639,640	600,958	560,010	519,190	478,768	438,168	399,012	357,380	315,554	275,882	234,638	197,426	161,930	128,070	96,618
Mean	52.102	52.593	53.980	55.053	55.517	55.893	56.155	56.243	56.361	56.539	56.789	56.955	57.045	57.096	57.119
25th to 75th pctile effect size	-0.534	-0.922	-0.833	-0.398	-0.581	-0.609	-0.479	-0.349	-0.469	-0.597	-0.935	-0.957	-0.735	-0.809	-0.424

Notes: These table presents the regression results from model (1), using labor market outcomes measured at each age between 18 to 32 as outcomes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A9: Robustness of Results on Respiratory Disease Hospitalizations in First Year of Life

	Respiratory Disease Hospitalizations in First Year of Life				
	(1)	(2)	(3)	(4)	(5)
Younger	0.042***	0.041***	0.037***	0.039***	0.041***
	(0.003)	(0.003)	(0.005)	(0.003)	(0.003)
Disease index	0.011***	0.007***	0.004**		
	(0.001)	(0.001)	(0.002)		
Younger x disease index	0.013***	0.013***	0.014***		
	(0.001)	(0.001)	(0.002)		
Disease index (# Diagnosis)				0.005***	
				(0.001)	
Younger x disease index (# Diagnosis)				0.010***	
				(0.000)	
Disease index (# Kids)					0.012***
					(0.001)
Younger x disease index (# Kids)					0.014***
					(0.001)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Observations	1,230,180	1,230,180	1,230,180	1,230,180	1,230,180
Mean	0.070	0.070	0.070	0.070	0.070
25th to 75th pctile effect size	0.024	0.024	0.026	0.024	0.024

Notes: Each column in the table presents results from estimating different versions of model (1). The outcome is the number of hospitalizations with a respiratory disease primary diagnosis. Column (1) presents results using the baseline model. Column (2) adds municipality-specific linear time trends, while column (3) adds maternal fixed effects. Column (4) uses a disease index in which we count number of diagnoses for respiratory conditions in hospitalizations including both primary and non-primary diagnoses. Column (5) uses a disease index in which we calculate the number of children with at least one respiratory disease diagnosis (i.e., counting the number of children and not the total number of diagnoses). Column (6) uses a disease index calculated based only on the first three months of life for the focal child (instead of 12 months). See notes under Table 2 for more details about our baseline model and control variables. Standard errors are clustered on the child's municipality of birth in all models. The "25th to 75th pctile effect size" row reports the magnitude of the differential effect of an increase in the disease exposure index from the 25th to the 75th percentile of the distribution for younger siblings. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A10: Robustness of Results on Labor Force Participation at Ages 25–32

	Labor Force Participation at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.012***	-0.011***	-0.004	-0.012***	-0.012***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Disease index	0.005***	0.003*	0.005**		
	(0.002)	(0.002)	(0.002)		
Younger x disease index	-0.001	-0.001	-0.001		
	(0.001)	(0.001)	(0.001)		
Disease index (# Diagnosis)				0.004***	
				(0.001)	
Younger x disease index (# Diagnosis)				-0.001	
				(0.001)	
Disease index (# Kids)					0.006***
					(0.002)
Younger x disease index (# Kids)					-0.001
					(0.001)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,377,733	2,377,733	2,357,933	2,377,733	2,377,733
Mean	0.698	0.698	0.699	0.698	0.698
25th to 75th pctile effect size	-0.002	-0.002	-0.001	-0.002	-0.002

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is an indicator for being in the labor force. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A11: Robustness of Results on Wage (conditional on employment) at Ages 25–32

	Wage Income (conditional on employed) at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-703.461***	-1,028.582***	-41.997	-750.064***	-699.210***
	(252.761)	(227.929)	(265.050)	(255.345)	(254.269)
Disease index	112.481	32.048	386.881**		
	(105.634)	(108.617)	(165.842)		
Younger x disease index	-235.420***	-105.425	-406.381***		
	(79.905)	(68.915)	(107.262)		
Disease index (# Diagnosis)				125.681	
				(79.052)	
Younger x disease index (# Diagnosis)				-154.704***	
				(55.361)	
Disease index (# Kids)					112.318
					(110.936)
Younger x disease index (# Kids)					-248.531***
					(83.914)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	1,616,792	1,616,792	1,593,028	1,616,792	1,616,792
Mean	57,067.833	57,067.833	57,277.058	57,067.833	57,067.833
25th to 75th pctile effect size	-330.707	-148.097	-568.817	-299.064	-333.163

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is the wage income (conditional on employment), converted into 2010 USD$. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A12: Robustness of Results on Log Wage (conditional on employment) at Ages 25–32

	Log Wage Income (conditional on employed) at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.011**	-0.016***	0.002	-0.012**	-0.011**
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
Disease index	0.002	0.000	0.007***		
	(0.002)	(0.002)	(0.002)		
Younger x disease index	-0.006***	-0.004**	-0.009***		
	(0.002)	(0.001)	(0.002)		
Disease index (# Diagnosis)				0.002	
				(0.001)	
Younger x disease index (# Diagnosis)				-0.004***	
				(0.001)	
Disease index (# Kids)					0.002
					(0.002)
Younger x disease index (# Kids)					-0.006***
					(0.002)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	1,612,736	1,612,736	1,588,915	1,612,736	1,612,736
Mean	10.856	10.856	10.860	10.856	10.856
25th to 75th pctile effect size	-0.008	-0.005	-0.013	-0.008	-0.008

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is the natural log of the wage income (conditional on employment), converted into 2010 USD$. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A13: Robustness of Results on Total Income (winsorized) at Ages 25–32

	Total Income (winsorized) at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-651.411***	-773.137***	-121.566	-641.670***	-647.346***
	(176.874)	(163.360)	(161.701)	(176.767)	(179.240)
Disease index	210.312**	82.615	332.821***		
	(101.336)	(91.361)	(101.733)		
Younger x disease index	-192.866**	-144.121**	-239.734***		
	(73.955)	(63.522)	(63.513)		
Disease index (# Diagnosis)				172.703**	
				(75.577)	
Younger x disease index (# Diagnosis)				-142.295***	
				(52.463)	
Disease index (# Kids)					210.939*
					(109.181)
Younger x disease index (# Kids)					-203.963**
					(78.729)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,377,733	2,377,733	2,357,933	2,377,733	2,377,733
Mean	49,345.560	49,345.560	49,438.876	49,345.560	49,345.560
25th to 75th pctile effect size	-276.802	-206.844	-343.709	-283.461	-281.089

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is the gross income (winsorized at 1-99 percentile), converted into 2010 USD$. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A14: Robustness of Results on Log Total Income at Ages 25–32

	Log Total Income at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.008	-0.011**	0.009*	-0.007	-0.008
	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
Disease index	0.005*	0.002	0.009***		
	(0.003)	(0.003)	(0.003)		
Younger x disease index	-0.006***	-0.005**	-0.007***		
	(0.002)	(0.002)	(0.002)		
Disease index (# Diagnosis)				0.004*	
				(0.002)	
Younger x disease index (# Diagnosis)				-0.005***	
				(0.002)	
Disease index (# Kids)					0.006*
					(0.003)
Younger x disease index (# Kids)					-0.007***
					(0.003)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,372,145	2,372,145	2,352,321	2,372,145	2,372,145
Mean	10.652	10.652	10.654	10.652	10.652
25th to 75th pctile effect size	-0.009	-0.007	-0.010	-0.010	-0.009

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is the natural log of the gross income, converted into 2010 USD$. Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A15: Robustness of Results on Income Percentile at Ages 25–32

	Income Percentile at Age 25-32				
	(1)	(2)	(3)	(4)	(5)
Younger	-0.759***	-0.917***	-0.086	-0.745***	-0.755***
	(0.209)	(0.194)	(0.197)	(0.209)	(0.212)
Disease index	0.288**	0.124	0.418***		
	(0.124)	(0.108)	(0.120)		
Younger x disease index	-0.238***	-0.175**	-0.307***		
	(0.090)	(0.077)	(0.078)		
Disease index (# Diagnosis)				0.234**	
				(0.092)	
Younger x disease index (# Diagnosis)				-0.176***	
				(0.063)	
Disease index (# Kids)					0.292**
					(0.133)
Younger x disease index (# Kids)					-0.251***
					(0.095)
Municipality FEs	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes
Municipality Trends	No	Yes	No	No	No
Mother FEs	No	No	Yes	No	No
Age FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,377,726	2,377,726	2,357,926	2,377,726	2,377,726
Mean	56.566	56.566	56.580	56.566	56.566
25th to 75th pctile effect size	-0.342	-0.251	-0.441	-0.351	-0.347

Notes: See notes under Appendix Table A9 for more details about the specifications and variables. The sample includes sibling pairs at ages 25–32, with each observation at the person-by-age level. The outcome is the income percentile (calculated using the population of the same age in each year). Age fixed effects are included in all regressions. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A16: Effect of the Respiratory Disease Exposure Index on the Respiratory Hospitalization at Age 0, by Time of Exposure

	Resp. Hosp. (Age 0)	
	(1)	(2)
Younger	0.039***	0.060***
	(0.003)	(0.005)
Disease index (1st half)	0.010***	
	(0.002)	
Younger x disease index (1st half)	0.028***	
	(0.001)	
Disease index (2nd half)		0.018***
		(0.002)
Younger x disease index (2nd half)		0.012***
		(0.002)
Municipality FEs	Yes	Yes
Birth YM FEs	Yes	Yes
Family Background Controls	Yes	Yes
Observations	1,230,180	1,230,180
Mean	0.070	0.070
25th to 75th pctile effect size	0.026	0.011

Notes: These table presents the regression results from model (1), separately for disease index constructed based on the 1st half year of life (Column (1)) or 2nd half year of life (Column (2)). All regressions include municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A17: Effect of the Respiratory Disease Exposure Index on the Labor Market Outcomes at Age 25–32, by Time of Exposure

	(1) Labor Market Participation	(2) Wage (cond. on emp.)	(3) Log Wage (cond. on emp.)	(4) Total Income (winsorized)	(5) Log Total Income	(6) Income Percentile
Panel A: Disease Index based on the 1st Half Year of Life						
Younger	-0.010***	-725.203***	-0.012***	-641.269***	-0.008*	-0.738***
	(0.003)	(232.639)	(0.004)	(152.623)	(0.005)	(0.181)
Disease index (1st half)	0.007***	156.872	0.002	287.033**	0.011***	0.381**
	(0.003)	(136.867)	(0.003)	(134.591)	(0.004)	(0.165)
Younger x disease index (1st half)	-0.004**	-461.645***	-0.011***	-402.460***	-0.013***	-0.505***
	(0.002)	(122.803)	(0.003)	(110.074)	(0.004)	(0.136)
Panel B: Disease Index based on the 2nd Half Year of Life						
Younger	-0.015***	-926.864***	-0.016***	-875.314***	-0.015***	-1.046***
	(0.003)	(244.012)	(0.005)	(167.080)	(0.005)	(0.197)
Disease index (2nd half)	0.005**	162.930	0.004	233.711*	0.003	0.324**
	(0.002)	(163.643)	(0.003)	(130.153)	(0.004)	(0.156)
Younger x disease index (2nd half)	0.000	-264.446	-0.007**	-185.727	-0.007	-0.220
	(0.002)	(159.312)	(0.003)	(143.186)	(0.005)	(0.172)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,377,733	1,616,792	1,612,736	2,377,733	2,372,145	2,377,726
Mean	0.698	57,067.833	10.856	49,345.560	10.652	56.566

Notes: These table presents the regression results from model (1), separately for disease index constructed based on the 1st half year of life (Panel A) or 2nd half year of life (Panel B). All regressions include age, municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A18: Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Educational Outcomes, by Age of Observation

	(1) Age 18	(2) Age 19	(3) Age 20	(4) Age 21	(5) Age 22	(6) Age 23	(7) Age 24	(8) Age 25	(9) Age 26	(10) Age 27	(11) Age 28	(12) Age 29	(13) Age 30	(14) Age 31	(15) Age 32
Panel A: High School Graduation															
Younger	0.000	0.003**	-0.020***	-0.046***	-0.051***	-0.044***	-0.040***	-0.039***	-0.037***	-0.032***	-0.029***	-0.024***	-0.016**	-0.014**	-0.015**
	(0.000)	(0.001)	(0.007)	(0.008)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
Disease index	-0.000	0.001*	0.005*	0.004*	-0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.004	0.005	0.005	0.001
	(0.000)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Younger x disease index	-0.000	-0.001	-0.005**	-0.004	-0.001	-0.001	-0.001	0.000	0.001	-0.000	-0.000	-0.002*	-0.002	-0.003*	-0.000
	(0.000)	(0.000)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Observations	631,358	593,636	548,484	505,086	466,120	423,458	379,938	333,864	291,574	252,552	213,880	179,486	147,524	117,450	89,542
Mean	0.000	0.010	0.274	0.571	0.687	0.746	0.777	0.795	0.809	0.819	0.828	0.836	0.843	0.850	0.857
25th to 75th pctile effect size	-0.000	-0.001	-0.013	-0.009	-0.002	-0.002	-0.001	0.000	0.002	-0.000	-0.000	-0.005	-0.005	-0.005	-0.001
Panel B: College Graduation															
Younger	-0.000	-0.000	0.000	-0.000	-0.000	-0.003**	-0.013***	-0.024***	-0.040***	-0.045***	-0.048***	-0.046***	-0.044***	-0.044***	-0.042***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.004)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.009)	(0.008)	(0.009)
Disease index	-0.000	-0.000	-0.000	0.000	0.000*	0.001**	0.005***	0.006***	0.003	-0.000	-0.003	-0.000	0.001	0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
Younger x disease index	-0.000	-0.000	0.000	0.000	0.000	-0.001***	-0.003**	-0.005*	-0.002	-0.001	-0.003	-0.003	-0.002	-0.002	-0.002
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Observations	631,358	593,636	548,484	505,086	466,120	423,458	379,938	333,864	291,574	252,552	213,880	179,486	147,524	117,450	89,542
Mean	0.000	0.000	0.000	0.000	0.004	0.026	0.091	0.189	0.283	0.348	0.389	0.416	0.436	0.451	0.463
25th to 75th pctile effect size	-0.000	-0.000	0.000	0.000	0.000	-0.002	-0.007	-0.012	-0.005	-0.002	-0.006	-0.006	-0.005	-0.003	-0.005

Notes: These table presents the regression results from model (1), using whether graduated from high school or college by each age between 18 to 32 as outcomes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A19: Effect of Respiratory Disease Exposure Index in First Year of Life on Test Scores, Younger versus Older Siblings

	(1)	(2)
	Danish Test Score (9th Grade)	Math Test Score (9th Grade)
Younger	-0.119***	-0.136***
	(0.013)	(0.014)
Disease index	0.001	0.002
	(0.005)	(0.004)
Younger x disease index	-0.008*	-0.003
	(0.005)	(0.006)
Municipality FEs	Yes	Yes
Birth YM FEs	Yes	Yes
Family Background Controls	Yes	Yes
Observations	470,848	472,582
Mean	0.099	0.139
25th to 75th pctile effect size	-0.014	-0.006

Notes: See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the individual and municipality of birth level. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A20: Effect of the Respiratory Disease Exposure Index on the Education Outcomes, by Time of Exposure

	(1) Danish Test Score (9th Grade)	(2) Math Test Score (9th Grade)
Panel A: Disease Index based on the 1st Half Year of Life		
Younger	-0.120***	-0.129***
	(0.010)	(0.012)
Disease index (1st half)	0.002	0.003
	(0.008)	(0.007)
Younger x disease index (1st half)	-0.016**	-0.012
	(0.007)	(0.009)
Panel B: Disease Index based on the 2nd Half Year of Life		
Younger	-0.130***	-0.148***
	(0.011)	(0.011)
Disease index (2nd half)	0.003	0.002
	(0.007)	(0.005)
Younger x disease index (2nd half)	-0.008	0.002
	(0.007)	(0.008)
Municipality FEs	Yes	Yes
Birth YM FEs	Yes	Yes
Family Background Controls	Yes	Yes
Observations	470,848	472,582
Mean	0.099	0.139

Notes: These table presents the regression results from model (1), separately for disease index constructed based on the 1st half year of life (Panel A) or 2nd half year of life (Panel B). All regressions include age, municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A21: Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Mental Health Outcomes, by Age of Observation

	(1) Age 16	(2) Age 17	(3) Age 18	(4) Age 19	(5) Age 20	(6) Age 21	(7) Age 22	(8) Age 23	(9) Age 24	(10) Age 25	(11) Age 26
Panel A: Number of Private Psychiatric Clinic / Psychiatric Hospital Visits											
Younger	-1.541**	-1.784**	-1.697**	-2.527**	-1.964	-2.599*	-1.705	-2.764**	-3.803**	-5.072***	-1.802
	(0.701)	(0.716)	(0.763)	(0.969)	(1.355)	(1.354)	(1.146)	(1.312)	(1.709)	(1.643)	(1.772)
Disease index	0.131	-0.231	-0.265	-0.579	0.015	0.042	0.132	-0.149	-0.455	-0.676	0.567
	(0.286)	(0.307)	(0.288)	(0.428)	(0.464)	(0.480)	(0.536)	(0.474)	(0.674)	(0.695)	(0.825)
Younger x disease index	0.342	0.449*	0.291	0.496	0.295	0.242	0.574*	1.084***	1.054**	1.618***	0.572
	(0.235)	(0.235)	(0.248)	(0.374)	(0.408)	(0.417)	(0.299)	(0.329)	(0.439)	(0.454)	(0.531)
Observations	676,592	636,598	599,572	559,928	515,674	472,988	435,258	396,194	354,252	312,552	273,620
Mean	7.380	8.547	10.884	12.929	14.150	14.735	15.226	15.833	16.823	16.861	16.755
25th to 75th pctile effect size	0.845	1.108	0.713	1.216	0.721	0.591	1.392	2.632	2.503	3.779	1.276
Panel B: Any Private Psychiatric Clinic / Psychiatric Hospital Visit											
Younger	-0.072	-0.046	-0.372***	-0.232	-0.209	-0.208	-0.210	-0.332*	-0.394*	-0.114	0.027
	(0.151)	(0.116)	(0.139)	(0.157)	(0.157)	(0.173)	(0.180)	(0.193)	(0.218)	(0.221)	(0.240)
Disease index	0.096	0.081	0.066	0.091	0.038	-0.009	-0.041	-0.170**	-0.104	0.072	0.019
	(0.064)	(0.061)	(0.054)	(0.065)	(0.053)	(0.067)	(0.069)	(0.072)	(0.083)	(0.101)	(0.108)
Younger x disease index	0.014	0.002	0.047	0.000	-0.022	-0.025	0.035	0.067	0.093	0.041	0.060
	(0.045)	(0.034)	(0.039)	(0.050)	(0.047)	(0.053)	(0.051)	(0.057)	(0.062)	(0.072)	(0.058)
Observations	676,592	636,598	599,572	559,928	515,674	472,988	435,258	396,194	354,252	312,552	273,620
Mean	2.400	2.612	2.972	3.302	3.533	3.676	3.731	3.783	3.901	3.875	3.802
25th to 75th pctile effect size	0.035	0.005	0.116	0.001	-0.054	-0.061	0.085	0.162	0.221	0.095	0.135
Panel C: Number of Private Psychiatric Clinic Visits											
Younger	-0.488	-1.493**	-1.008	-2.629***	-2.162**	-1.795*	-1.283	-1.628	-2.915**	-4.914***	-2.811*
	(0.627)	(0.674)	(0.638)	(0.782)	(1.069)	(1.024)	(0.944)	(1.155)	(1.412)	(1.424)	(1.499)
Disease index	0.143	-0.305	-0.491*	-0.793**	-0.149	-0.091	0.258	0.361	-0.738	-0.916	-0.251
	(0.289)	(0.264)	(0.275)	(0.375)	(0.367)	(0.425)	(0.427)	(0.473)	(0.530)	(0.580)	(0.628)
Younger x disease index	0.071	0.403*	0.175	0.526*	0.321	0.037	0.275	0.594	0.731**	1.530***	1.116***
	(0.240)	(0.208)	(0.212)	(0.303)	(0.285)	(0.325)	(0.246)	(0.370)	(0.342)	(0.386)	(0.412)
Observations	714,696	674,302	637,718	599,162	554,066	511,310	473,774	433,326	393,812	351,938	311,156
Mean	4.098	4.968	6.618	8.209	9.085	9.396	9.818	10.258	10.950	11.143	11.131
25th to 75th pctile effect size	0.177	0.996	0.431	1.289	0.789	0.090	0.671	1.437	1.775	3.632	2.609

Effect of the Respiratory Disease Exposure Index on the Younger Siblings' Labor Market Outcomes, by Age of Observation (continued)

	(1) Age 16	(2) Age 17	(3) Age 18	(4) Age 19	(5) Age 20	(6) Age 21	(7) Age 22	(8) Age 23	(9) Age 24	(10) Age 25	(11) Age 26
Panel D: Any Private Psychiatric Clinic Visit											
Younger	-0.021	0.007	-0.112	-0.182*	-0.144	-0.301***	-0.255***	-0.286**	-0.308***	-0.400***	-0.377***
	(0.051)	(0.061)	(0.079)	(0.094)	(0.089)	(0.098)	(0.095)	(0.126)	(0.115)	(0.111)	(0.135)
Disease index	0.029	0.010	-0.017	-0.060	-0.006	-0.039	-0.020	-0.037	-0.058	-0.053	-0.081
	(0.031)	(0.031)	(0.033)	(0.040)	(0.038)	(0.040)	(0.042)	(0.051)	(0.053)	(0.053)	(0.062)
Younger x disease index	-0.003	0.002	0.035	0.047	0.019	0.046	0.083***	0.083**	0.067*	0.125***	0.122***
	(0.017)	(0.020)	(0.023)	(0.036)	(0.025)	(0.037)	(0.029)	(0.041)	(0.035)	(0.035)	(0.036)
Observations	714,696	674,302	637,718	599,162	554,066	511,310	473,774	433,326	393,812	351,938	311,156
Mean	0.559	0.683	0.945	1.207	1.331	1.375	1.406	1.430	1.474	1.495	1.489
25th to 75th pctile effect size	-0.007	0.006	0.086	0.116	0.046	0.113	0.202	0.201	0.162	0.297	0.285
Panel E: Number of Psychiatric Hospital Visits											
Younger	-1.101**	-0.143	-0.325	-0.042	-0.169	-0.457	-0.426	-0.362	-0.504	0.350	0.162
	(0.438)	(0.310)	(0.303)	(0.395)	(0.524)	(0.673)	(0.493)	(0.709)	(0.640)	(0.688)	(0.890)
Disease index	-0.056	0.121	0.296**	0.095	0.196	0.161	-0.019	-0.302	-0.142	0.317	0.148
	(0.108)	(0.115)	(0.117)	(0.169)	(0.184)	(0.229)	(0.195)	(0.210)	(0.199)	(0.294)	(0.318)
Younger x disease index	0.256***	0.019	-0.016	0.007	0.064	0.026	0.081	0.280	0.344**	-0.101	0.035
	(0.086)	(0.087)	(0.079)	(0.112)	(0.171)	(0.219)	(0.149)	(0.212)	(0.157)	(0.224)	(0.252)
Observations	676,592	636,598	599,572	559,928	515,674	472,988	435,258	396,194	354,252	312,552	273,620
Mean	3.375	3.711	4.378	4.967	5.354	5.636	5.679	5.860	5.933	5.799	5.723
25th to 75th pctile effect size	0.632	0.048	-0.039	0.018	0.155	0.062	0.197	0.681	0.817	-0.236	0.079
Panel F: Any Psychiatric Hospital Visit											
Younger	-0.050	-0.032	-0.234*	-0.070	-0.012	0.087	0.019	0.023	-0.138	0.296*	0.177
	(0.148)	(0.113)	(0.125)	(0.126)	(0.160)	(0.151)	(0.158)	(0.141)	(0.200)	(0.168)	(0.194)
Disease index	0.072	0.072	0.104***	0.109**	0.070	0.043	-0.010	-0.105*	-0.090	0.033	0.013
	(0.052)	(0.045)	(0.038)	(0.053)	(0.049)	(0.061)	(0.061)	(0.053)	(0.066)	(0.078)	(0.084)
Younger x disease index	0.011	-0.003	0.002	-0.039	-0.062	-0.097**	-0.057	-0.018	0.059	-0.098**	-0.008
	(0.039)	(0.028)	(0.032)	(0.035)	(0.044)	(0.049)	(0.049)	(0.042)	(0.048)	(0.049)	(0.052)
Observations	676,592	636,598	599,572	559,928	515,674	472,988	435,258	396,194	354,252	312,552	273,620
Mean	1.922	2.039	2.208	2.362	2.496	2.593	2.617	2.654	2.714	2.664	2.616
25th to 75th pctile effect size	0.028	-0.007	0.005	-0.097	-0.151	-0.237	-0.138	-0.043	0.140	-0.229	-0.019

Notes: These table presents the regression results from model (1), using whether mental health care utilization as outcomes. At each age, we require both of the siblings are observed in the data. All regressions include municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.

Table A22: Effect of the Respiratory Disease Exposure Index on the Mental Health Outcomes at Age 16–26, by Time of Exposure

	(1) Number of Visits	(2) Any Visit	(3) Number of Clinic Visits	(4) Any Clinic Visit	(5) Number of Hospital Visits	(6) Any Hospital Visit
Panel A: Disease Index based on the 1st Half Year of Life						
Younger	-1.222**	-0.006	-1.344***	-0.114***	0.090	0.101
	(0.512)	(0.085)	(0.381)	(0.037)	(0.228)	(0.070)
Disease index (1st half)	-0.080	0.065	-0.285	-0.037	0.137	0.093**
	(0.379)	(0.052)	(0.305)	(0.028)	(0.128)	(0.038)
Younger x disease index (1st half)	0.822***	0.062	0.636***	0.073***	0.162	-0.008
	(0.273)	(0.042)	(0.193)	(0.019)	(0.141)	(0.034)
Panel B: Disease Index based on the 2nd Half Year of Life						
Younger	-0.490	0.116	-0.844**	-0.051	0.292	0.169**
	(0.465)	(0.084)	(0.389)	(0.037)	(0.230)	(0.071)
Disease index (2nd half)	-0.288	0.033	-0.469	-0.044	0.144	0.062
	(0.387)	(0.062)	(0.350)	(0.035)	(0.124)	(0.045)
Younger x disease index (2nd half)	0.231	-0.035	0.235	0.023	0.001	-0.061**
	(0.264)	(0.039)	(0.230)	(0.021)	(0.137)	(0.030)
Municipality FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birth YM FEs	Yes	Yes	Yes	Yes	Yes	Yes
Family Background Controls	Yes	Yes	Yes	Yes	Yes	Yes
Age FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,067,930	6,067,930	6,488,017	6,488,017	6,067,930	6,067,930
Mean	13.623	3.490	8.585	1.213	5.299	2.535

Notes: These table presents the regression results from model (1), separately for disease index constructed based on the 1st half year of life (Panel A) or 2nd half year of life (Panel B). All regressions include age, municipality, year-month of birth fixed effect, and family background controls. See notes under Table 2 for more details about the specifications and variables. Standard errors are clustered on the child's municipality of birth in all models. Significance levels: * p<0.1 ** p<0.05 *** p<0.01.