Extended Abstract for EPC 2024

Understanding Inequalities in Smoking in Pregnancy: Disentangling Maternal Age and Social Disadvantage

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Background and Motivation

Much academic work has documented that there exist individual associations between social disadvantage and maternal smoking in pregnancy. For example, researchers have found that mothers who give birth at younger ages, have low occupational status, or who are single, are more likely to smoke during pregnancy and less likely to quit smoking (Cnattingius 2004; Kandel, Griesler and Schaffran 2009; Pampel 2006; Pampel and Rogers 2004). Other studies have noted that women who do not complete secondary education, or who pursue vocational educational qualifications, are significantly more likely to smoke during pregnancy (Harkonen et al. 2018; Kinnunen et al. 2015; Rumrich et al. 2018). Yet the mechanisms driving such disparities continue to be poorly understood. Different forms of social disadvantage are likely to shape the likelihood of smoking before pregnancy, or quitting during pregnancy, in different and intersecting ways.

An important puzzle in the literature is the relationship between maternal age versus other forms of social status on SIP, since more disadvantaged women also tend to have children at younger ages. Moreover, most smoking initiation begins in adolescence, while the probability of quitting smoking increases over the adult life course. Therefore, disadvantaged women are not only more likely to have ever begun smoking, they are also less likely to have quit by the time they become pregnant. Disentangling the mechanisms leading to such disparities over time is required.

We contribute to this literature using register data on maternal smoking which is captured at the start, and end, of pregnancy, for all births in Finland from 1987 to 2016. We first apply demographic decomposition methods to examine how inequalities are driven by differences in smoking at onset versus quitting. Using g-decomposition, we estimate a series of counterfactual estimands, asking: how would disparities in SIP by education, or occupation, change if less advantaged women were to give birth at the same ages as more advantaged women? Finally, using an alternative approach, we run simulations using a subset of disadvantaged, multiparous women to examine how smoking status changes as maternal age increases. This is important because socio-economic disparities in smoking in SIP are a critical mechanism for the intergenerational transmission of inequality in high-income countries. Maternal smoking is the largest behavioural risk factor globally which deleteriously impacts birth outcomes, infant mortality and morbidity, and chronic childhood conditions (Blumenshine et al. 2010; Mortensen, Helweg-Larsen and Andersen 2011). SIP restricts oxygen to the foetus (Kandel et al. 2009) and is closely associated with higher risk of preterm birth, low birth weight and

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a range of chronic conditions (Cnattingius 2004; Kandel et al. 2009; Ko et al. 2014; Soneji and Beltran-Sanchez 2019; van den Berg et al. 2013; Varela et al. 2009) (Soneji and Beltran-Sanchez 2019). Although policies to reduce adult smoking, as well as interventions to promote smoking cessation for expectant mothers, have contributed to lower overall rates of smoking in pregnancy, disparities in maternal SIP remain stark across most high-income countries (Bonello et al. 2023) including Finland (Harkonen et al. 2018; Rumrich et al. 2018). Such inequalities in maternal smoking are likely to have long-lasting implications for health and socioeconomic inequalities amongst the next generation of children, throughout childhood and into adulthood (Jaakkola 2004).

Using linked birth records for all children born in Finland from 1987 to 2016, we document temporal trends in inequalities in SIP across four markers of maternal social disadvantage - maternal age, marital status, education and occupation. These measures are chosen because they consistently emerge as the most strongly linked with probability of smoking in pregnancy in high-income countries (Bonello et al. 2023; Harkonen et al. 2018). First, we leverage data on maternal smoking at onset of pregnancy and the time of birth to examine whether disparities along these axes are driven by differential rates of smoking prior to pregnancy (i.e. by initiation of adult smoking) or by differential rates of quitting during the first trimester of pregnancy. Such dynamics are important to understand for two reasons. The effects of smoking in pregnancy on the foetus are greatly reduced when mothers quit smoking during the first trimester; research suggests that women who quit smoking had only slightly reduced rates of preterm birth and intrauterine growth compared to those who did not smoke (Raisanen et al. 2014). Exposure to tobacco smoke in-utero starves the foetus of oxygen and is particularly harmful to intrauterine growth in the third trimester. In addition, understanding how prior smoking and quitting affects disparities in smoking over time can inform policy and programming to reduce rates of maternal smoking. For example, much emphasis has been placed on psycho-social, pharmacological, and more recently financial interventions to promote smoking cessation in early pregnancy. Yet, most smoking initiation has been found to begin in adolescence (Maralani 2013, 2014). If disparities in are primarily driven by significantly higher rates of maternal smoking prior to pregnancy, then comparable rates of successful quitting among different groups will not significantly reduce these inequalities. Targeted interventions, in this case, might be more effective when focussed on reducing smoking uptake and continuation among young women at the time of initiation.

Next, we aim to disentangle the effects of maternal age from other forms of social disadvantage by applying g-decomposition analyses to better understand how the age distribution of mothers contributes to disparities in SIP by marital status, occupation, and education. Our analysis is set within a counterfactual framework and is explicitly causal. We ask, if single mothers were to have the same age at birth distribution as mothers who were partnered, how would disparities in maternal smoking by partnership status change? If mothers with vocational qualifications were to have the same age at birth distribution as mothers with academic qualifications, how would this alter educational disparities in smoking in pregnancy? Finally, we apply simulation models using a subset of disadvantaged women who are multiparous, to understand how smoking status may change for the same women who give birth at both younger and older ages. In this way we attempt to control for the effects of unobserved maternal characteristics, such as personality traits or psychosocial health, on smoking outcomes.

Data and Methods

The analyses use data from Finnish population-based registers, which have a system of person identification numbers that allows researchers to track individuals and family members across multiple domains and generations by linking databases. We conduct analyses for each country separately. Data on maternal smoking status for Finland is taken from the Medical Birth Register for all singleton births from 1987–2016. These cohorts are selected because full and complete medical birth registers are collected from 1987 onwards in Finland providing detailed comparative data on birth outcomes, prenatal and postnatal health, including maternal cigarette smoking. We exclude births to mothers born outside Finland as we are unable to obtain accurate information on educational attainment. We link children to their fathers using data from the Population Registry (DVV) which was collected from 1964 onwards. Educational attainment data for both parents is taken from the census files conducted every five years in 1970, 1975, 1980, 1985 and then annually from the yearly registry of education measured from 1987, owned by Statistics Finland. For additional analyses, we use data on income and social assistance from Finland's Register of Social assistance, collected since 1985.

The outcome variable is maternal smoking status at the end of pregnancy; this is a binary variable which is set to 1 for smoker and 0 for non-smoker. T. We measure maternal age at birth in years using data from the Medical Birth Register. In line with g-decomposition, we measure sets of pairwise disparities in SIP along four dimensions of social disadvantage: level of educational attainment, type of educational attainment, partnership status and occupation. We document absolute disparities in mean rates of maternal smoking at the time birth between a reference category (more socially advantaged) and a comparison category (representing greater social disadvantage). This measure is chosen because it is appropriate for g-formula decomposition, which requires two categories of outcomes to compare. We decompose the following disparities:

Reference category	***Disadvantage category***
Secondary or higher	*Less than secondary*
Academic qualification	*Vocational qualification*
Partnered	*Single*
White-collar occupation	*Manual occupation*

We measure educational attainment along two axes. First, we subdivide education by level of attainment. The reference category is (1) secondary or higher; this includes tertiary degree (university-level academic degree, post-secondary vocational or tertiary polytechnic degree) or upper-secondary education (general or vocational); and the disadvantaged category is (2) less than upper-secondary education. Our second measure of education focuses on the type of educational qualification obtained. Our reference category (1) is academic education; this includes university-level degree, academic/general upper-secondary degree and our second category (2) is non-academic education; this includes vocational/polytechnic tertiary or university degree, vocational upper-secondary degree, less than upper-secondary education. tween educational tracks by examining academic versus vocational qualifications. We have two categories for work; (1) white collar; and (2) blue-collar or manual. For marital status we have two categories; (1) partnered and (2) single.

We use population records to collect data on other socioeconomic and demographic markers, such as class (operationalised as parental educational attainment; low-class (less than secondary) or high-class (post-secondary), educational attainment of partner, employment status of partner.

First, we apply a form of Das Gupta's decomposition (Gupta 1978) to decompose the final smoking rate at the end of pregnancy into rates of quitting and non-smoking at onset. We can write the final rate of continued smoking during pregnancy, c_x, as $c_x = s_x - q_x . s_x = (1 - n_x)(1 - q_x)$, where n_x is the proportion of non-smokers at onset of pregnancy in category x, s_x is the proportion of women in category x who were smokers at onset of pregnancy (i.e. s_x = 1- n_x) , and q_x is the proportion of smokers s_x who quit during the first trimester[4].

Next, we use g-formula decomposition to examine contribution of underlying maternal age distribution to disparities in SIP. Decomposition using the g-formula (Sudharsanan and Bijlsma 2022) is motivated by recent advances in epidemiology (Jackson and VanderWeele 2018) and sociology (Lundberg 2022) which aim to situate decomposition within a causal inference framework. The key estimands in our analysis are the counterfactual absolute disparities in rates of SIP by education, occupation and marital status, if mothers in the less advantaged group were to have the same age at birth distribution as women in the more advantaged group. We apply the g-decomposition described in Sudharsanan and Bijlsma (2022) by regressing maternal age at birth on a set of covariates (confounders of the relationship between age and SIP). Then we regress SIP on maternal age with the same covariates. Using these estimates, we run simulations to form a 'natural course pseudo-population'[5] and a 'counterfactual pseudo-population'[6]. To address Monte Carlo error we simulate the natural course and counterfactual pseudo-populations multiple times to produce a more stable estimate of the absolute gaps in SIP.[7] We use bootstrapping to estimate the standard error of our decomposition[8], although we note that in this case the risk of population sampling error will be minimal since we use data on almost the entire population. Finally, we address other sources of bias related to self-reporting of smoking status and non-disclosure (Mannisto et al. 2016).

Expected Findings We first use demographic decomposition to examine the extent to which inequalities are driven by differences in smoking at onset versus quitting. Using g-decomposition, we then estimate a series of counterfactual estimands, asking: how would disparities in SIP by education, or occupation, change if less advantaged women were to give birth at the same ages as more advantaged women? Finally, we tackle this question using a different approach, and run simulations using a subset of disadvantaged, multiparous women to examine how smoking status changes for the same group of women as maternal age increases.

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[4] Therefore, the rate of non-smoking at onset of pregnancy and the quitting rate among mothers who do smoke are thus equally important contributions to the overall smoking rate in each category, with $smoking\_rate_{ed} \to 0$ as either $n_{ed} \to 1$ or $quit\_rate_{ed} \to 1$.

[5] Here we use the coefficients from the mediator model(s) with the observed confounder values to simulate mediator values for each individual in the data. We use the coefficients from the outcome model(s) together with the observed confounder values and the new simulated mediator values to simulate the outcome for each individual in the data, then estimate rates of SIP for the advantaged and disadvantaged group.

[6] Here we take the non-reference group, and use the coefficients from the mediator models with the observed confounder values to simulate counterfactual mediator values that follow the distribution of maternal age distribution in the reference group. We use the coefficients from the outcome models together with the observed confounder values and simulated mediator values (counterfactual for the non-reference group and natural course for the reference group) to simulate the outcome for each individual in the data.

[7] We use the natural course as the reference in the contribution rather than compare two counterfactual scenarios so that the counterfactual scenarios are compared to the "as is" observed conditions.

[8] We use a bootstrap procedure to capture sampling uncertainty, drawing with replacement a fresh sample of size equal to the original data before step 1, conducting the entire analysis *k* times, and then estimating the standard error of our decomposition estimates as the standard deviation of the estimates from the *k* bootstrap samples.

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