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Birth outcomes following unexpected job loss: a matched-sibling design

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Abstract

Background: Research documents social and economic antecedents of adverse birth outcomes, which may include involuntary job loss. Previous work on job loss and adverse birth outcomes, however, lacks high-quality individual data on, and variation in, plausibly exogenous job loss during pregnancy and therefore cannot rule out strong confounding.
Methods: We analysed unique linked registries in Denmark, from 1980 to 2017, to examine whether a father's involuntary job loss during his spouse's pregnancy increases the risk of a low-weight (i.e. <2500 grams) and/or preterm (i.e. <37 weeks of gestational age) birth. We applied a matched-sibling design to 743 574 sibling pairs.
Results: Results indicate an increased risk of a low-weight birth among infants exposed *in utero* to fathers' unexpected job loss [odds ratio (OR) = 1.37, 95% confidence interval (CI): 1.07, 1.75]. Sex-specific analyses show that this result holds for males (OR = 1.70, 95% CI: 1.14, 2.53) but not females (OR = 1.24, 95% CI: 0.80, 1.91). We find no relation with preterm birth.
Conclusions: Findings support the inference that a father's unexpected job loss adversely affects the course of pregnancy, especially among males exposed *in utero*.

Key words: Infant health, job loss, low birthweight, preterm birth, siblings, unemployment

Introduction

As the global economic downturn following the COVID-19 pandemic made clear, involuntary job loss serves as a potent and undesirable stressor.[1] Job loss reduces both short-term income and long-term earnings,[2] increases the risk of subsequent job loss,[3] disrupts social routines and a sense of purpose,[4] precedes adverse life events (e.g. divorce)[5] and raises the risk of mortality.[6] During the Great Recession in the USA, job losses occurred especially among low socio-economic status (SES) groups,[7] which further increased income inequality after the recession.[8]

Key Messages

- We examine whether an exogenous shock—a spouse's unexpected job loss due to a plant closure—adversely affects the course of pregnancy.
- Results using a matched-sibling design indicate an increased risk of a low-weight, but not preterm, birth among infants exposed *in utero*.
- The adverse effects of job loss on low birthweight are concentrated among males.
- The stress of the spouse's job loss, rather than reductions in income per se, may perturb fetal growth.

Work documenting job loss as a potent stressor, combined with the widely replicated observation of strong SES disparities in birth outcomes, has stimulated research on whether job loss per se worsens pregnancy outcomes. Given that pregnancy appears sensitive to a wide variety of stressors,[9–14] scholars have examined the potential relation between job loss and birth outcomes using a range of study designs. Bozzoli and Quintana-Domeque,[15] Margerison-Zilko and collegues[16,17] and others[18–20] estimate the perinatal response to macroeconomic recessions by measuring downturns at the ecological level. Lindo,[21] by contrast, examines birth outcomes in a small sample of mothers who self-report that their husbands lost a job within the past 2 years. These studies do not converge, with some showing adverse birth outcomes[16–18,21] and others showing better-than-expected outcomes.[19,20]

Previous work, although addressing important questions, lacks high-quality individual data on, and variation in, the plausibly exogenous job loss of a spouse during pregnancy. This limitation leaves open the question of whether involuntary job loss in a family per se affects the course of pregnancy. Ecological analyses, for instance, examine a heterogeneous population of births in which most spouses of pregnant persons do not lose a job. By contrast, individual-level studies of job loss in a family rely on self-reports; those who report job loss, however, show a greater prevalence of health problems *before* unemployment relative to those who stay employed.[22–26] To the extent that a spouse's health issues (e.g. smoking, high body mass index, mental disorder) correlate with morbidity among the pregnant spouse, a self-report of recent job loss may 'signal' pre-existing health issues.

Additionally, Lindo's individual-level study uses self-reported job loss of the spouse within two years before a live birth.[21] Self-reports may display measurement error and the use of a two-year window cannot discern whether unemployment affects the course of pregnancy or merely the decision to conceive. The decision to select into fertility during economic uncertainty varies substantially by SES and other factors that correlate with adverse birth outcomes.[27,28] For this reason, it remains unclear to what extent unmeasured factors that affect the decision to conceive account for Lindo's findings.

We address these inferential limitations by using unique data registries in Denmark to identify a plausibly exogenous shock—a father's job displacement due to a plant closure—and link this information to the cohabiting spouse's birth outcome. Our linked register data set with administrative measures of job loss is also >250 times larger than that of Lindo's analysis.[21] Based on prior literature, we hypothesize that pregnant persons whose husbands undergo job displacement will show an elevated risk of low birthweight (LBW; <2500 grams) and/or preterm birth (PTB; <37 weeks of gestational age). Importantly, we use a matched-sibling design that minimizes bias due to unmeasured maternal factors that affect birth outcomes.

In addition to the study design improvements and ability to minimize bias, our analysis contributes to the literature in two key ways. First, identification of the extent to which job loss worsens the course of pregnancy may uncover causes of perinatal health disparities that fall along SES. Second, results may suggest policies for pregnant women whose families face imminent job loss.

Methods

Data and variables

We retrieved information on birthweight, gestational age and socio-demographic characteristics of parents from several national registers in Denmark including the Medical Birth Register (MFR). Denmark's MFR appears comprehensive with respect to the ability to link individual data to other national health and non-health registers, including the Population Register, the Education Register, the Income Statistics Register and the Integrated Database for Labour Market Research (IDA).[29] The MFR includes a unique personal identification number that links the mother to the birth as well as to the spouse at the time of the birth. Importantly, the MFR also includes information

on gestational age, which permits estimation of the date of conception. We used 1980 as the start date of our analysis given that information on key exposure variables begins in this year. Our data set continues until 2017, the last year of data available to us at the time of our tests.

We, consistent with the economics literature, retrieved data on individual employment, plants and firms operating in Denmark from IDA registers and used, as the independent variable, job loss due to the closure of a single-plant firm in the private sector.[22] Plant closures represent a plausibly exogenous cause of job loss for several reasons. They primarily occur due to macroeconomic forces or firm-level factors (rather than to individual worker performance or behaviour) and happen relatively quickly, which permits clear documentation of their timing. Examination of the temporal variation of plant closures supports a positive correlation between its prevalence and broader macroeconomic cycles in Denmark, further supporting the measurement validity of the exposure (Supplementary Material Section 1, available as Supplementary data at *IJE* online).

Denmark's IDA registers include individual-level information about labour-market attachment to specific firms and number of days worked.[29] The MFR has a high percentage of birth records that link to the mother and to the father/spouse, which permits classification of the mother's exposure during the pregnancy to the spouse's unexpected job loss. We classified exposure *in utero* to a father's involuntary job loss if the date of the job loss followed the estimated date of conception but preceded the date of delivery. We focused on exposure to job loss among spouses of pregnant women for two reasons. First, women's decisions to participate and/or leave the workforce may relate to the course of pregnancy and, as a result, preclude establishment of temporal order between exposure and outcome.[30,31] Second, relatively few women over the test period worked in single-plant firms that qualified for exposure to job loss, thus limiting the study power in examining women's job loss. A detailed description of classification of exposure to involuntary job loss and sensitivity checks using data available in the IDA and Income registers appears in Supplementary Material Section 2 (available as Supplementary data at *IJE* online).

Statistical analyses

A key concern with examining the relation between social and/or economic stressors during pregnancy and birth outcomes involves confounding by a common cause.[11] Unmeasured maternal or familial characteristics may precede both the exposure (e.g. spouse's job loss) and the outcome (e.g. low birthweight, preterm birth) and correlate with both, thereby biasing any exposure/outcome relation. As discussed above, plant closures precipitate job loss largely outside of an individual's control in that broader macroeconomic forces are considered the root cause.

By contrast, other work that uses self-reported job loss or other forms of paternal unemployment as the key exposure to maternal stress during pregnancy risks confounding by several variables. The two largest sets of potential confounders that may precede both job loss during pregnancy and the adverse pregnancy outcome itself involve social or health selection into environments that increase risk of stress. For instance, a couple who each suffers from depression or other health issues (e.g. alcohol-use disorder) may show an increased risk of both father's job loss and adverse birth outcomes. Another example involves the social selection of women with relatively few marriage prospects into unions with men who are of relatively lower SES and have less job stability. This social stratification may precede both a spouse's job loss and an adverse birth outcome. Within this context, in our study we contend that the use of a plausibly exogenous exposure—i.e. an external exposure of plant closures in which the timing is independent of common causes of exposure and outcome at the level of the individual—minimizes confounding.

Our use of the exogenous exposure of plant closures is analogous to intent-to-treat logic based on instrumental variables.[32,33] We consider maternal stress related to paternal job loss as the 'treatment' or X. Y is the birth outcome of the mother (e.g. low birthweight). Z ('treatment assignment') is the father's job loss due to a plant closure. Z serves as a valid estimator ('instrumental variable') of the effect of X on Y if three conditions apply: Z precedes, and affects, X; Z affects Y only through X; and Z and Y share no common cause. Given these conditions, the Z→Y effect approximates the X→Y effect (see causal diagram in Supplementary Material Section 3, available as Supplementary data at *IJE* online).

Matched-sibling design

To minimize confounding by a common cause, we not only specified a plausibly exogenous exposure variable but, consistently with the literature, used a matched-sibling design to reduce bias if a spouse's job loss is not entirely exogenous to the birth outcome.[21] The matched-sibling design, although enhancing internal validity under conditions such as ours in which potential confounders are shared across siblings but the exposure of interest is not,[34] requires that we focus our test on mothers with at least two live births over the test period ($n = 743\ 574$) (see sample selection flow chart in Figure 1). Only discordant sibling pairs—or pairs that differ in outcome and exposure—contribute to the estimated association in conditional

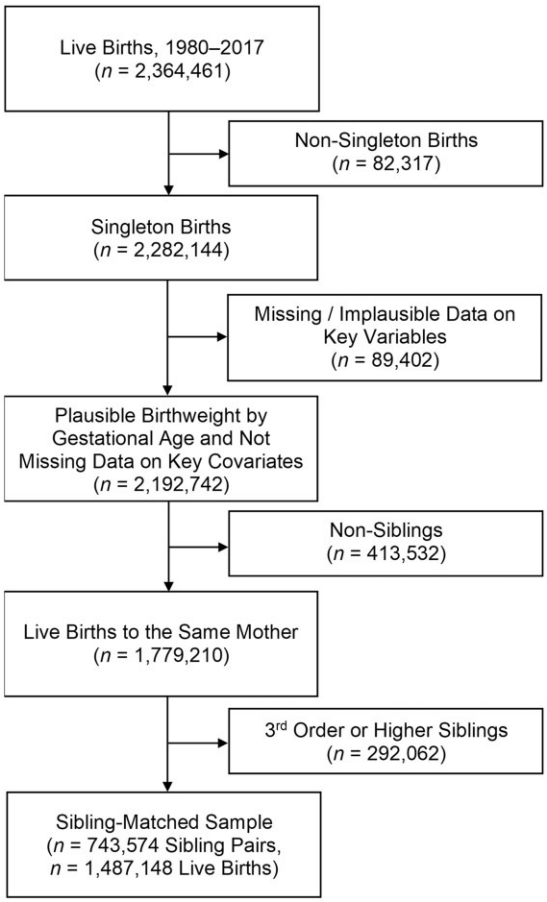

Figure 1. Sample selection process for 743,574 sibling pairs in the sibling-matched sample.

logistic-regression models (described below) where the outcome and exposure are dichotomous.[34]

Like Lindo,[21] we estimate models that compare the birth outcome of an infant exposed (in our case, *in utero*) to job loss to the outcome of an infant born to the same mother prior to job loss. In other words, we identify the estimated effect of a spouse's job loss by the comparison of siblings born before vs after displacement (p. 871). The sibling 'match', according to this logic, serves as a counterfactual approximation of the birth outcome to that mother had the spouse's job loss not occurred. Our approach, moreover, improves on Lindo's analysis in that we more precisely define exposure to job loss as displacement that occurs during the pregnancy with the second sibling.

We focus our matched-sibling analyses on sibling pairs in which the second sibling is exposed to job loss—and exclude pairs in which the first sibling is exposed to job loss—for two reasons. First, the literature finds that ambient shocks in general, and economic shocks in particular, may affect subsequent fertility decisions (i.e. whether or not to attempt to conceive again) as well as fertility timing (i.e. inter-birth interval).[35] Thus, the inclusion of sibling pairs for whom the parents experienced job loss and subsequently chose to conceive may bias results in an unknown direction. Second, past work examining birth outcomes in years after job loss considers these births as exposed.[19,21] Whereas our strict definition of job loss would classify births conceived after the job loss as unexposed, we acknowledge this potential 'contamination' in which the income and stress-related sequelae of job loss could persist for several years.

Model specifications

We analysed associations between job loss and adverse birth outcomes using several sibling-control models. We first estimated the conditional logit (i.e. log-odds) of low birthweight in the second sibling. The logit is conditional since we condition on the matched-sibling pair and use information about the first sibling to adjust for confounding. The dependent variable is LBW (yes/no) of the second sibling and the exposure is whether or not the second sibling is exposed to job loss. We adjust for the birth outcome (i.e. LBW) of the first sibling and non-shared confounders. In addition, the matched-sibling approach controls for unmeasured time-stable maternal or familial factors that may correlate with both job loss and adverse birth outcomes.[21,34,36] These confounders could include, for instance, SES or parental demographic factors that precede a spouse's decision to seek employment at a plant that ultimately closes. We further controlled for observed time-varying socio-demographic characteristics including age of mother and father, highest education completed by mother and father, and parity (i.e. at the time of the second pregnancy).

Given the debate in the sibling design literature regarding the extent to which control for birth outcomes in the first delivery introduces 'collider bias', we repeated the matched-sibling analysis but removed the control for low birthweight of the first delivery and conditioned the logistic regression on an identifier for the sibling pair (Supplementary Material Section 4, available as Supplementary data at *IJE* online). In addition, we assessed whether the results of the matched-sibling design analyses agree with those using a maternal fixed-effects (FE) strategy, which enjoys more use in economics (Supplementary Material Section 4, available as Supplementary data at *IJE* online).

We then repeated analyses using preterm birth as the dependent variable. Given that previous research documents sex-specific responses to stressors,[10,37,38] we also examined males and females separately for the subset of data from 1997 to 2017—the time period in which sex information on the live birth is fully available—and conducted tests of additive and multiplicative interactions (i.e. between

exposure to paternal job loss and infant sex) (Supplementary Material Section 5, available as Supplementary data at *IJE* online).

Sensitivity tests

We performed several sensitivity checks to assess the robustness of results. First, we repeated the conditional logistic-regression analyses, additionally controlling for infant sex (Supplementary Material Section 6, available as Supplementary data at *IJE* online). Next, we specified linear-regression models using continuous measures of birthweight and gestational age at delivery as dependent variables in separate models (Supplementary Material Section 7, available as Supplementary data at *IJE* online). We also conducted a negative control analysis in which we defined, as the 'false exposure', a father's job loss occurring in the same calendar year as the infant's birth but *after* the date of delivery (Supplementary Material Section 8, available as Supplementary data at *IJE* online). We then used a more restrictive definition of the date of the job loss (i.e. no earlier than 1 month after the estimated date of conception) to ensure that any results that supported our hypothesis did not arise from slight misclassifications of the date of the job loss or the date of conception (Supplementary Material Section 9, available as Supplementary data at *IJE* online). Lastly, we relaxed the matched-sibling restriction and conducted sensitivity checks of results for all mothers with at least one live birth by conducting a propensity-score analysis that matched subjects based on the probability of exposure to job loss due to plant closure (Supplementary Material Section 10, available as Supplementary data at *IJE* online).

Results

Table 1 describes the socio-demographic characteristics of parents and live births in Denmark according to sibling order and the job-loss status of the father. Of the 743 574 sibling pairs, a small fraction ($n = 2336$) meet the strict criterion of exposure (i.e. second sibling exposed *in utero* to a father's job loss due to plant closure). Parents in the exposed category appear slightly younger and less educated than those classified as never exposed. In addition, consistently with our expectation, the mean number of days worked among fathers of exposed pregnancies (i.e. second sibling, far-right column) is much lower than days worked among fathers of unexposed pregnancies (i.e. 130 vs 275 days per year for the matched first sibling).

Figure 2 plots the crude (i.e. unadjusted) relation, by sibling birth order, between exposure to involuntary job loss during pregnancy and low birthweight. The solid black line indicates 'never exposed' pregnancies and documents, consistent with the literature,[35] differences in low birthweight by birth order in which second-born siblings show a lower prevalence of low birthweight than do first-born siblings. The dotted grey line compares siblings in which the second (but not the first) sibling is exposed *in utero* to a father's involuntary job loss. Here, we observe no differences by birth order; in addition, for males only, exposed second siblings show a greater prevalence of low birthweight than do first siblings.

Adjusted logistic-regression analysis (Table 2) supports the inference of increased risk of a low-weight birth among siblings exposed *in utero* to fathers' unexpected job loss [odds ratio (OR) = 1.37, 95% confidence interval (CI): 1.07, 1.75]. Alternative sibling-control models, including a matched-sibling analysis that does not control for low birthweight of the first sibling (Supplementary Table S3, available as Supplementary data at *IJE* online) and maternal FE analyses (Supplementary Table S4, available as Supplementary data at *IJE* online), show consistent results. Inference also remains essentially unchanged in models controlling for infant sex (Supplementary Table S7, available as Supplementary data at *IJE* online), specifying continuous birthweight as the dependent variable (Supplementary Table S8, available as Supplementary data at *IJE* online) and using a more restrictive definition of the date of the job loss (Supplementary Table S11, available as Supplementary data at *IJE* online). Examination of gestational length, however, indicates no relation between exposure to paternal job loss and preterm birth (Table 3). This result persists when using the continuous outcome of gestational age at delivery (Supplementary Table S9, available as Supplementary data at *IJE* online).

Logistic-regression analyses stratified by sex suggest that the positive job loss/low birthweight result holds for males but not females, although the confidence intervals are less precise owing to the smaller subset of data years used (Table 2; OR for males = 1.70, 95% CI: 1.14, 2.53; OR for females = 1.24, 95% CI: 0.80, 1.91). Formal tests of additive and multiplicative interactions (Supplementary Tables S5 and S6, available as Supplementary data at *IJE* online, respectively) cannot reject the null. However, the sign and direction of the coefficients support a stronger relation between job loss and low birthweight among males (vs females).

Building on the low-birthweight result in the sibling-matched sample (which rejected the null), we relaxed the sibling design strategy and conducted a propensity-score analysis that compares low birthweight in a sample of live births (including non-siblings) matched on the probability of exposure to paternal job loss. Consistent with the results of the sibling-control analyses, the positive relation between job loss and low birthweight remains statistically

Table 1 Characteristics of parents and live births by father's job loss status and sibling order in the sibling-matched sample ($n = 743\,574$ sibling pairs), Denmark, 1980–2017

Characteristic	Father never lost job due to plant closure ($n = 741\,238$)				Father lost job due to plant closure during second pregnancy ($n = 2336$)			
	First sibling		Second sibling		First sibling		Second sibling	
	n	%	*n*	%	*n*	%	*n*	%
Maternal age								
<20	35 107	4.74	2759	0.37	153	6.55	7	0.30
20–24	215 856	29.12	77 449	10.45	709	30.35	285	12.20
25–29	326 415	44.04	267 787	36.13	979	41.91	796	34.08
30–34	138 252	18.65	281 328	37.95	424	18.15	873	37.37
35–39	24 279	3.28	97 553	13.16	68	2.91	343	14.68
≥40	1329	0.18	14 362	1.94	3	0.13	32	1.37
Maternal education								
None reported	2148	0.29			8	0.35		
Primary school	108 954	14.84			400	17.26		
Upper secondary	269 727	36.73			848	36.60		
Some higher	282 696	38.50			878	37.89		
BA or higher	70 812	9.64			183	7.90		
Immigrant status								
Danish	540 071	89.69	622 039	89.71	1777	87.24	1981	87.50
Immigrant	55 756	9.26	64 774	9.34	224	11.00	246	10.87
Descendant	6345	1.05	6609	0.95	36	1.77	37	1.63
Parity								
First birth	682 334	93.05	0	0	1727	74.92	68	2.92
Second birth	37 744	5.15	660 968	89.36	521	22.60	1676	71.96
Third or more	13 193	1.80	56 083	7.58	57	2.47	585	25.12
Paternal age								
<20	5086	0.88	476	0.07	38	1.98	1	0.05
20–24	70 568	12.22	23 882	3.56	268	13.98	125	5.83
25–29	230 277	39.88	155 711	23.19	740	38.60	509	23.75
30–34	185 869	32.19	273 602	40.74	597	31.14	791	36.91
35–39	62 574	10.84	151 413	22.55	206	10.75	514	23.99
≥40	23 110	4.00	66 485	9.90	68	3.55	203	9.47
Paternal education								
None reported	1029	0.14			2	0.09		
Primary school	132 465	18.18			466	20.24		
Upper secondary	376 474	51.67			1280	55.60		
Some higher	156 784	21.52			419	18.20		
BA or higher	61 812	8.48			135	5.86		
Birth characteristics								
Male[a]	185 558	51.46	228 071	51.30	751	50.67	853	50.68
Preterm	38 295	5.17	27 422	3.70	125	5.35	97	4.15
Low weight	31 278	4.22	20 017	2.70	84	3.60	83	3.55
Paternal employment	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Annual income (DKK)	150 922	(134 222)	187 155	(180 687)	161 255	(89 625)	190 907	(114 931)
Unemployment benefits (DKK)	4050	(14 037)	3582	(14 204)	5597	(16 765)	12 672	(27 025)
Days worked	300	(110)	305	(110)	275	(122)	130	(86)

BA, bachelor of arts; DKK, Danish krone.

[a]Data on infant sex are available for 1997–2017.

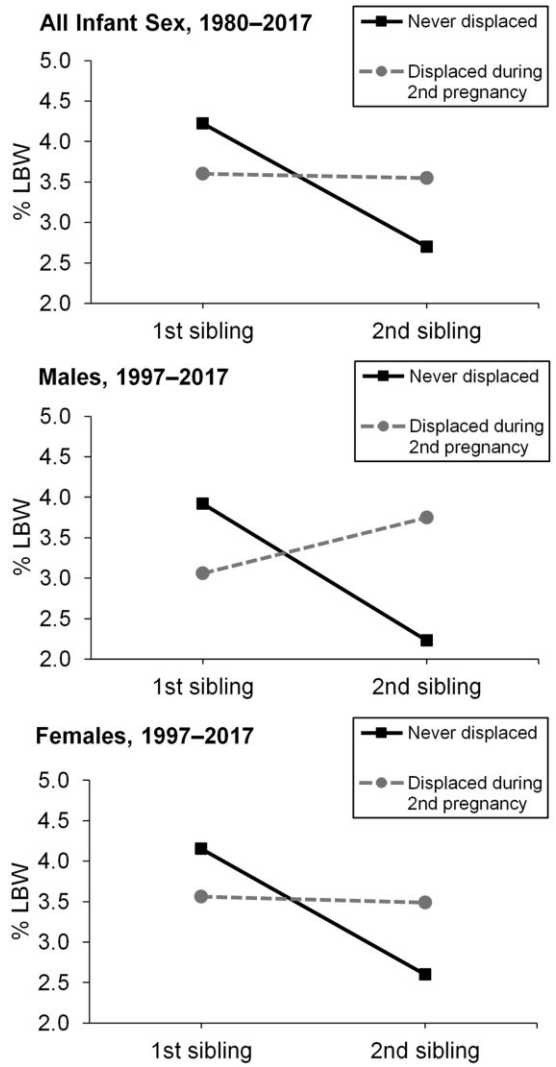

Figure 2. Unadjusted prevalence of low birthweight by father's job loss status and sibling order in the sibling-matched sample (n=743,574 sibling pairs). Abbreviations: LBW, low birthweight.

detectable in the full sample and among males but not females (Supplementary Table S13, available as Supplementary data at *IJE* online).

Discussion

We set out to examine whether unexpected job loss in a household during pregnancy precedes an increased risk of a low-weight and/or preterm birth. We based our hypothesis on previous literature that, although suggestive, does not converge, relies mainly on ecological measures of unemployment and cannot rule out several key rival explanations.[16–21] Results from our unique population-based register in Denmark, 1980–2017, support that the risk of a low-weight birth increases among persons whose spouses unexpectedly suffer job displacement during pregnancy. We observe no relation with preterm birth. Additional analyses indicate the robustness of the low-birthweight results to various specifications and that the low-birthweight findings are concentrated among male live births. Findings in Denmark support the inference that unexpected job loss adversely affects the course of pregnancy, especially among males *in utero*.

The strengths of our study include the ability to identify (from employment, plant and firm records) plausibly exogenous job loss in a household. This exposure, unlike other measures of unemployment such as self-reported job loss, minimizes bias due to unmeasured confounding by health and social factors that correlate strongly with, and precede, unemployment. In addition, the matched-sibling design permits control for time-invariant characteristics of a mother that may predispose her to delivering a low-weight and/or preterm infant. We note that the bias of sibling controls due to collider stratification on common causes of sibling discordance has been shown elsewhere to be weak when the exposure is not heavily confounded, which is the case with involuntary job displacement in this study.[34] The ability to identify the precise timing of the job displacement also, unlike earlier work, permits establishment of exposure *in utero*. This identification further strengthens the inference that job loss during pregnancy, rather than job-related stressors before the decision to conceive, adversely affects birthweight. Lastly, the robustness of the results to various sensitivity analyses (including alternative sibling-control model specifications and propensity-score matching) further supports internal validity.

A principal limitation involves the unknown external validity of the study. The matched-sibling design precludes inference to mothers with only one live birth and results in reduced sample size and statistical power. Our analytic sample, moreover, necessarily includes spouses who worked during the pregnancy of the first sibling. For this reason, we may have included couples who are, on average, healthier than couples in which the spouse is unemployed. In addition, the focus on exposure to job loss among second siblings does not permit control for the countervailing (i.e. protective) effect of birth order on low birthweight.[39] This limitation, however, likely biases our discovered low-birthweight result downward. In addition, the consistency of the low-birthweight results across various specifications, and when using birthweight as a continuous metric, further minimizes the likelihood of bias induced by excluding sibling pairs with the same outcome.[40]

We did not have full information on spontaneous terminations, which limited our ability to quantify bias due to exposure-related fetal loss. Previous research in Denmark reports increased spontaneous terminations following ambient economic downturns.[11] This work indicates that individual-level stressors such as unexpected job loss may

Table 2 Estimated associations[†] between a father's job loss due to plant closure and low birthweight overall and by infant sex[a] in the sibling-matched sample ($n = 743\,574$ sibling pairs), Denmark, 1980–2017

Parameter	All			Males[b]			Females[c]		
	OR	95% CI		OR	95% CI		OR	95% CI	
Job loss	1.37	1.07,	1.75	1.70	1.14,	2.53	1.24	0.80,	1.91
LBW (first sibling)	8.74	8.40,	9.08	9.22	8.53,	9.97	9.46	8.78,	10.19
Maternal age									
<20	1.30	1.02,	1.65	1.72	1.10,	2.69	1.23	0.77,	1.96
20–24 (ref.)									
25–29	0.86	0.80,	0.91	0.79	0.69,	0.91	0.81	0.71,	0.92
30–34	0.96	0.90,	1.03	0.90	0.78,	1.04	0.87	0.76,	1.00
35–39	1.25	1.16,	1.35	1.08	0.92,	1.27	1.06	0.91,	1.24
≥40	1.59	1.42,	1.78	1.37	1.08,	1.73	1.41	1.13,	1.76
Paternal age									
<20	1.24	0.78,	1.97	1.51	0.62,	3.67	1.64	0.76,	3.57
20–24 (ref.)									
25–29	0.88	0.80,	0.96	1.08	0.88,	1.31	0.93	0.78,	1.11
30–34	0.83	0.76,	0.91	1.03	0.84,	1.26	0.87	0.72,	1.04
35–39	0.88	0.80,	0.97	1.11	0.90,	1.37	0.91	0.75,	1.10
≥40	0.94	0.85,	1.05	1.20	0.96,	1.50	0.98	0.80,	1.21
Maternal education									
None reported	0.67	0.51,	0.88	0.47	0.26,	0.83	0.67	0.41,	1.08
Primary (ref.)									
Upper secondary	0.73	0.70,	0.77	0.66	0.59,	0.73	0.76	0.68,	0.84
Some higher	0.62	0.59,	0.65	0.54	0.48,	0.60	0.63	0.56,	0.69
BA or higher	0.54	0.50,	0.58	0.47	0.41,	0.55	0.57	0.50,	0.66
Paternal education									
None reported	0.76	0.51,	1.12	1.20	0.67,	2.15	0.45	0.21,	0.98
Primary (ref.)									
Upper secondary	0.86	0.83,	0.90	0.89	0.81,	0.98	0.84	0.77,	0.92
Some higher	0.71	0.67,	0.75	0.75	0.67,	0.85	0.75	0.67,	0.83
BA or higher	0.72	0.67,	0.78	0.76	0.66,	0.88	0.83	0.72,	0.95
Parity									
2 births (ref.)									
≥3 births	1.32	1.25,	1.40	1.31	1.13,	1.52	1.31	1.13,	1.51
Immigrant status									
Danish (ref.)									
Immigrant	1.16	1.10,	1.23	1.21	1.09,	1.34	1.29	1.17,	1.42
Descendant	1.31	1.14,	1.52	1.16	0.91,	1.47	1.58	1.29,	1.94
Year of birth	0.99	0.99,	0.99	1.00	1.00,	1.01	1.01	1.00,	1.01

BA, bachelor of arts; CI, confidence interval; LBW, low birthweight; OR, odds ratio.

[†]All odds ratios in the table are adjusted for all other variables in the model.

[a]Sex-specific analyses are restricted to sibling pairs born between 1997 and 2017, the time period for which sex information on the live birth is fully available.

[b]Sample includes 185 582 sibling pairs born between 1997 and 2017 in which the second sibling is male ($n = 371\,164$ total live births).

[c]Sample includes 176 507 sibling pairs born between 1997 and 2017 in which the second sibling is female ($n = 353\,014$ total live births).

elevate the risk of pregnancy loss. The availability in recent years of high-quality register data in this area should permit examination of this common but understudied perinatal outcome.

Denmark provides relatively generous unemployment insurance benefits. For instance, the fathers in our study exposed to job displacement from a plant closure lost, on average, <10% of their annual income in the year of the displacement. This circumstance indicates that stress related to the life event of job loss, rather than the magnitude of an income shock per se, appears sufficient to induce perinatal sequelae. Previous work documents a variety of adverse family-related outcomes (e.g. divorce) that appear more likely following job loss.[35,41–44] Whereas our work focuses on job loss, it remains possible that other job-related stressors may

Table 3 Estimated associations[†] between a father's job loss due to plant closure and preterm birth overall and by infant sex[a] in the sibling-matched sample ($n = 743\,574$ sibling pairs), Denmark, 1980–2017

Parameter	All			Males[b]			Females[c]		
	OR	95% CI		OR	95% CI		OR	95% CI	
Job loss	1.02	0.81,	1.28	1.15	0.82,	1.62	0.86	0.56,	1.33
PTB (first sibling)	6.78	6.56,	7.01	6.58	6.21,	6.98	6.99	6.56,	7.44
Maternal age									
<20	1.37	1.12,	1.68	1.28	0.87,	1.88	1.43	0.96,	2.14
20–24 (ref.)									
25–29	0.85	0.81,	0.90	0.87	0.79,	0.96	0.78	0.69,	0.87
30–34	0.93	0.88,	0.98	0.94	0.84,	1.05	0.79	0.70,	0.89
35–39	1.18	1.10,	1.26	1.14	1.01,	1.29	1.04	0.91,	1.19
≥40	1.41	1.27,	1.55	1.39	1.16,	1.67	1.41	1.13,	1.76
Paternal age									
<20	0.92	0.84,	1.00	1.36	0.66,	2.83	1.77	0.87,	3.63
20–24 (ref.)									
25–29	0.88	0.81,	0.95	0.92	0.80,	1.06	0.91	0.78,	1.07
30–34	0.83	0.77,	0.90	0.84	0.73,	0.98	0.89	0.76,	1.05
35–39	0.87	0.80,	0.94	0.88	0.75,	1.03	0.94	0.79,	1.11
≥40	0.94	0.85,	1.05	0.92	0.78,	1.09	0.88	0.73,	1.06
Maternal education									
None reported	0.75	0.59,	0.95	0.41	0.25,	0.69	1.03	0.68,	1.55
Primary (ref.)									
Upper secondary	0.82	0.79,	0.85	0.76	0.70,	0.82	0.84	0.77,	0.92
Some higher	0.72	0.69,	0.75	0.67	0.61,	0.72	0.73	0.67,	0.80
BA or higher	0.62	0.59,	0.66	0.56	0.50,	0.62	0.67	0.59,	0.76
Paternal education									
None reported	0.81	0.58,	1.13	1.09	0.66,	1.78	0.49	0.24,	1.00
Primary (ref.)									
Upper secondary	0.90	0.87,	0.93	0.91	0.84,	0.97	0.91	0.84,	0.98
Some higher	0.81	0.77,	0.84	0.83	0.76,	0.90	0.80	0.73,	0.88
BA or higher	0.81	0.76,	0.86	0.83	0.75,	0.93	0.85	0.75,	0.96
Parity									
2 births (ref.)									
≥3 births	1.29	1.22,	1.36	1.28	1.14,	1.43	1.38	1.22,	1.56
Immigrant status									
Danish (ref.)									
Immigrant	1.11	1.06,	1.16	1.11	1.02,	1.20	1.10	1.01,	1.21
Descendant	1.07	0.93,	1.22	1.01	0.84,	1.23	1.10	0.89,	1.36
Year of birth	1.00	1.00,	1.00	1.00	0.99,	1.00	1.00	0.99,	1.00

BA, bachelor of arts; CI, confidence interval; OR, odds ratio; PTB, preterm birth.

[†]All odds ratios in the table are adjusted for all other variables in the model.

[a]Sex-specific analyses are restricted to sibling pairs born between 1997 and 2017, the time period for which sex information on the live birth is fully available.

[b]Sample includes 185 582 sibling pairs born between 1997 and 2017 in which the second sibling is male ($n = 371\,164$ total live births).

[c]Sample includes 176 507 sibling pairs born between 1997 and 2017 in which the second sibling is female ($n = 353\,014$ total live births).

affect the quality of the spousal relationship and, in turn, perinatal outcomes. Additional research may elucidate the relative contribution of these life events and income loss to the course of pregnancy.

The pattern of results indicates that a spouse's sudden job loss may affect intrauterine growth but not the timing of parturition. Although prior studies on maternal stressors report both low-weight and preterm birth responses,[45] a recent meta-analysis finds that birthweight appears more responsive to maternal stressors than does preterm labour,[46] which coheres with our findings. The literature, however, does not agree on the type, dose and timing of a stressor that would induce growth restriction.[47] A physiological response along the maternal hypothalamic–pituitary–adrenal axis,[47] a disruption in normal placental function[48] and/or maladaptive maternal behaviours may

play a role.[49–51] Additional research that examines behavioural and physiological measures of the mother following plausibly exogenous stressful experiences would greatly assist with advancing our understanding of these proposed mechanisms. Such research would also benefit from the examination of potential sex-specific responses given that our work and that of others find elevated sensitivity among males exposed to stressors *in utero*.[10,37,38,52]

For reasons that remain unclear, males more than females appear sensitive to ambient stressors *in utero*.[37] Many (but not all) reports of perinatal responses to natural and man-made disasters (e.g. terrorist attacks, earthquakes),[10,53–55] as well as broader economic downturns,[17] find relatively greater sensitivity among males. Although the mechanisms underlying sex differences remain unclear, male and female fetuses respond differently to experimental stimuli beginning at mid-gestation.[56] Absent data on spontaneous terminations, however, we cannot provide a fuller accounting of this potential male sensitivity *in utero* and its potential 'live-birth' bias in affecting the composition of males who ultimately survive to birth.[57] We are currently exploring the possibility of linking data on terminations (spontaneous and elective) to the plant closure information in the Danish registries.

Our work builds on Lindo's study of perinatal responses to self-reported job loss and contributes to the debate on whether job loss per se adversely affects the course of pregnancy.[21] Only replication of results can determine whether the findings in Denmark generalize to other countries with relatively less social and economic support for the unemployed (e.g. the USA). Another important extension involves understanding the nature of individual-level unemployment in the context of larger recessions such as that induced by the COVID-19 pandemic. The availability and generosity of social safety-net programmes often diminish following extended downturns. As a result, job loss during a regional downturn may strain families above and beyond the levels in which the job loss occurs during economic stasis or expansion. We encourage such work in societies and epochs with the ability to link high-quality data on unexpected job loss at the individual level to natality files for the population base.

Supplementary data

Supplementary data are available at *IJE* online.

Ethics approval

The authors have adhered to ethical standards in this work and obtained Institutional Review Board Approval from the University of California, Irvine (#2013–9716).

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Data availability

The data underlying this article cannot be shared publicly to guarantee the anonymity of subjects. Code is available upon request.

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Conflict of interest

None declared.

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