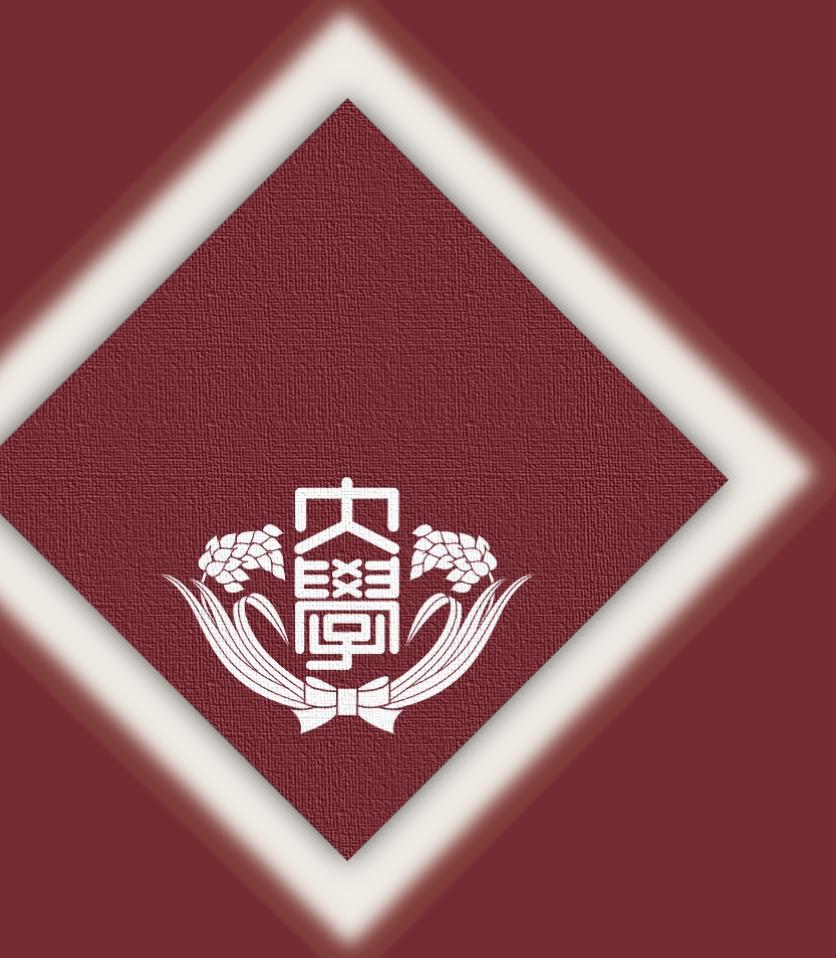


In Utero Exposure to Radiation Fear and Birth Outcomes: Evidence from Fukushima Nuclear Power Plant Accident



Rong Fu, PhD^{1,3}; Yichen Shen, PhD^{2,3}; Haruko Noguchi, PhD^{1,3}

¹Waseda University, ²Kanagawa University of Human Services,

³Waseda Institute of Social & Human Capital Studies (WISH)

Introduction

Health at birth—a key determinant of human capital development

- ◆ Maternal stress has a negative impact on birth outcomes (Fig 1.)

We focus on an understudied maternal stress—**fear of radiation exposure**

- ◆ Radiation fear of Japan's Fukushima Nuclear Power Plant (NPP) Accident in 2011

Why radiation fear?

1. Better identification of maternal stress
2. An increasingly relevant risk

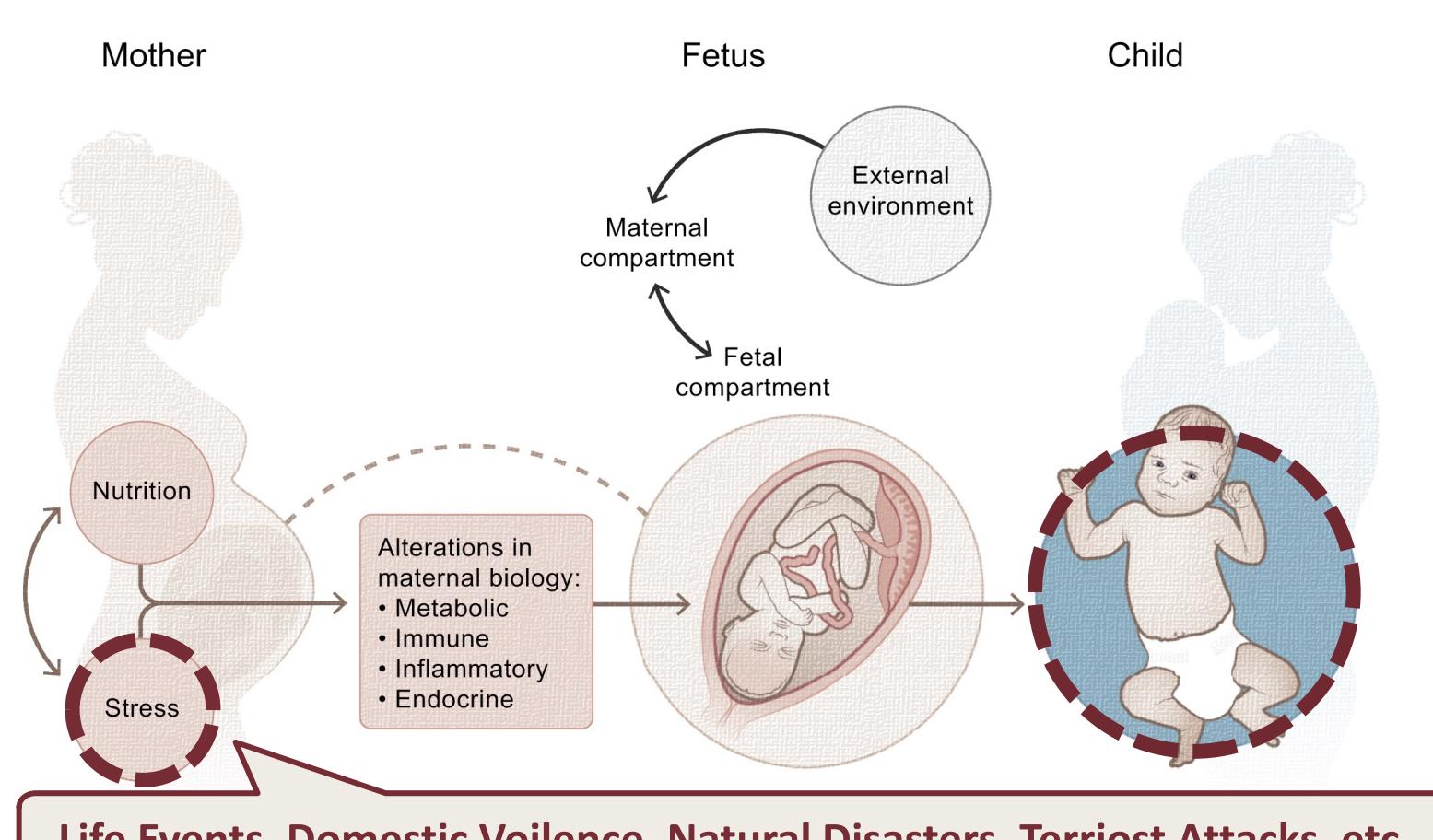


Fig. 1 Maternal stress and birth outcomes

Source: <https://www.japantimes.co.jp/news/2021/03/09/national/311-facts-today>

Source: DeCapo et al. (2019) Biological psychiatry

The Fukushima Accident

The most catastrophic consequence of the Great East Japan Earthquake (Fig. 2)

- ◆ The earthquake triggered a devastating tsunami (Fig. 3)
- ◆ The Fukushima NPP lost its entire cooling capacity due to the tsunami, leading to three hydrogen explosions (Fig. 4)
- ◆ Radioactive materials released; Evacuation ordered



Fig. 3 Tsunami induced by the earthquake.

Source: <https://www.japantimes.co.jp/news/2021/03/08/national/science-health/a-pandisaster-tsunami-warnings>

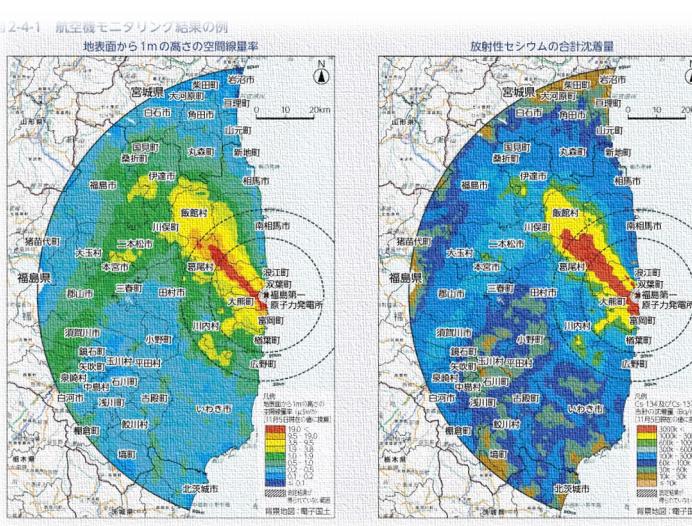


Fig. 4 Radioactive materials in air

Source: <https://empowerment.tsuda.ac.jp/detail/55620>

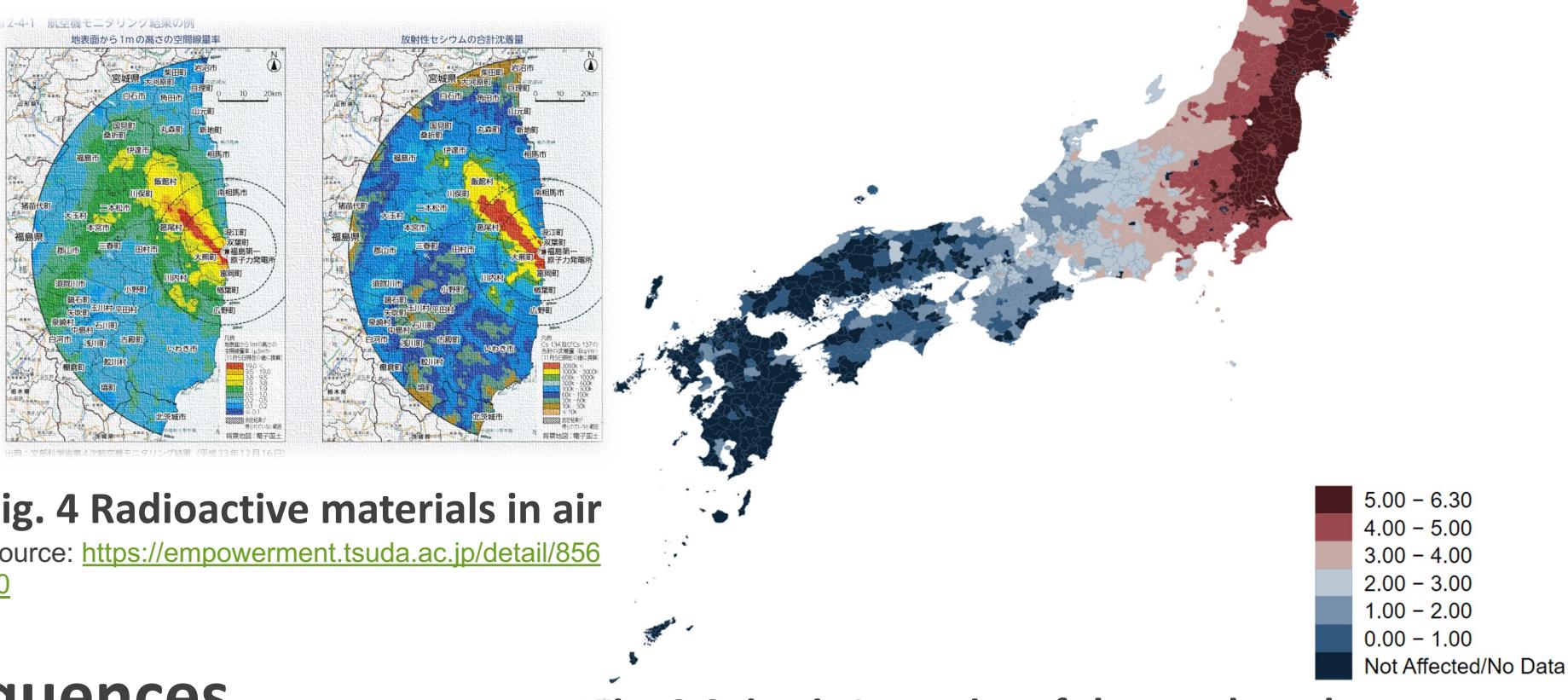


Fig. 2 Seismic Intensity of the earthquake

Radioactivity and the health consequences

- ◆ Limited in Fukushima prefecture; diminishing within a year following the accident

Radiation fear

- ◆ Nationwide-spread; a more pressing issue of the accident (Hasegawa et al., 2015)

Data and Measurement

Population data linkage

Health information

- ◆ At birth—universal birth records (Jun 2010 – Dec 2011)
- ◆ At age two and five—comprehensive survey of living conditions (CSLC, 2013 and 16)

Background characteristics

- ◆ Parental and residential information—2010 and 2015 censuses

Data Exclusion (gray areas in Fig. 5)

- ◆ Regions damaged by tsunami
- ◆ Regions contaminated by radioactivity (annual dose >1 mSv)

Measurements

	Variables
Health at Birth	(1) Birth weight (gram), (2) Low birth weight (LBW, <2500g), (3) Very low birth weight (VLBW, <1500g), (4) Extremely low birth weight (ELBW, <1000g)
Health at Age 2 and 5	(1) Any physical symptoms, (2) Respiratory, (3) Digestive, and (4) Skin symptoms; Seeking medical treatment or not for each symptom
Prenatal vs. Postnatal	Prenatal group $1[c \leq \text{Accident} < e_b]_i = 1$ Postnatal group $1[e_b \leq \text{Accident} \leq e_b + 280]_i = 1$ c — conception date e_b — the expected birthdate
Fear Level (Fig. 5)	High-fear (red areas, living < 30 km from an NPP), Moderate-fear (pink areas, 30–80 km from an NPP), Low-fear (blue areas, > 80 km from an NPP)
Covariates	Parental characteristics (parents' ages at conception, education, fathers' occupations), Earthquake impacts (seismic intensity × [dwelling type, the floor of dwelling, and length of residence]), Neonatal characteristics (gender and order of birth)

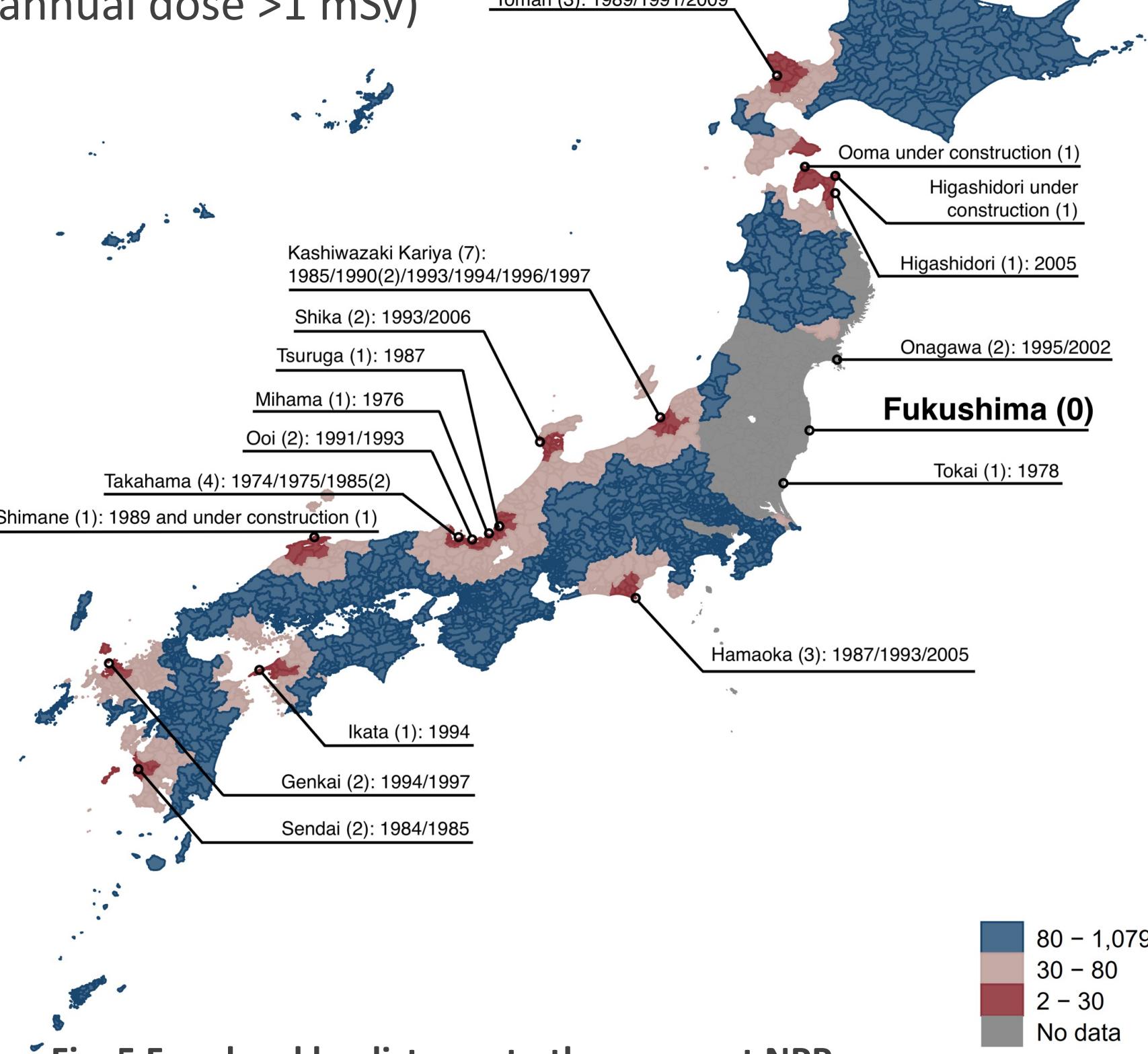


Fig. 5 Fear level by distance to the nearest NPP

Note: The numbers in the bracket indicate the number of nuclear reactors in operation, shut down for scheduled inspections, or under construction as of August 2022. The years indicate the ones of commencement of operation of each nuclear reactor in the municipalities.

Contact

Rong Fu, Waseda University, Japan

Email: nataliefu@waseda.jp

Website: <https://sites.google.com/view/nataliefu-homepage>

Methods

Prenatal vs. Postnatal Model

$$S = \{i: 1[c \leq \text{Accident} < e_b]_i = 1 | 1[e_b \leq \text{Accident} \leq e_b + 280]_i = 1\}$$

Estimate $y_{imc} = \beta_0 + \beta_1 \mathbf{1}[c \leq \text{Accident} < e_b]_{imc} + \lambda_m + \lambda_c + x_i' \tau + \epsilon_{imc}$,

for each newborn i who was born in municipality m and conceived in month c .

- ◆ β_1 — impact of in-utero radiation fear; λ_m and λ_c — municipality and conception-month fixed effects; x_i — covariates; ϵ_{imc} — the error term.

Validity Tests

- ◆ Systematical differences in background characteristics—No
- ◆ Changes in risks of abortion and stillbirth—No impact
- ◆ Confounding energy saving request—No discernible magnitude gap
- ◆ Placebo test of “accident” on Oct 12, 2020—No impact

A diff-in-diff Model

$$y_{imc} = \delta_0 + \delta_1 \mathbf{1}[c \leq \text{Accident} < e_b]_{imc} + \delta_2 \sum_{j=1}^2 \mathbf{1}[c \leq \text{Accident} < e_b]_{imc} \times \text{Fear}_j + \lambda_m + \lambda_c + x_i' \tau + \epsilon_{imc}$$

Validity Tests

- ◆ Systematical differences in background characteristics—No
- ◆ Inter- or intra-prefecture migration—No

Results and Conclusions

The adverse impact on birth outcomes

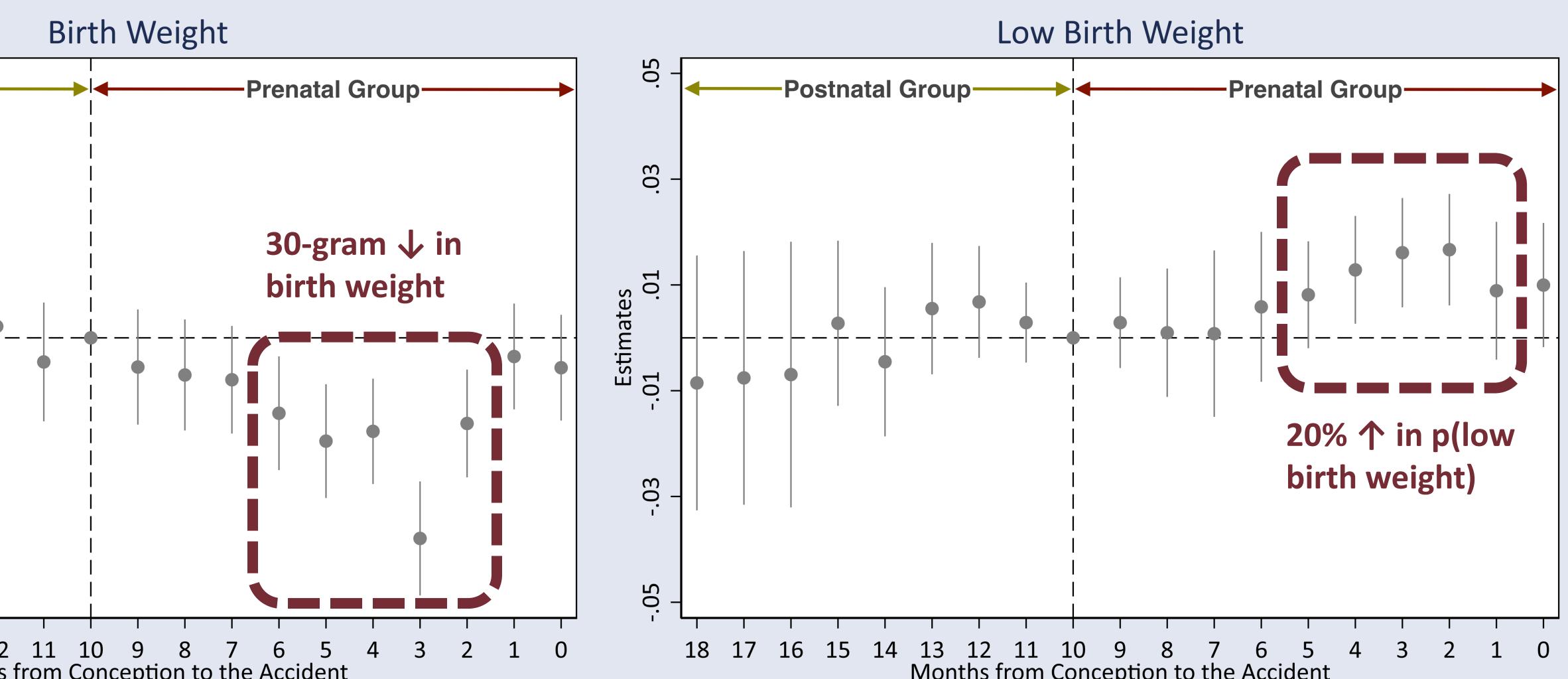


Fig. 6 The impact of in-utero radiation fear on birth weight and the likelihood of low birth weight

Some adverse impact at age two; little impact at age five

	Age Two				Age Five				Temporary impact on physical health
	Any	Respiratory	Digestive	Skin	Any	Respiratory	Digestive	Skin	
Panel A: Symptoms									
In-utero	0.0622 *	0.0726 **	0.0282 *	0.0291 *	0.0327	0.0297	0.0131 *	0.0031	(0.0352) (0.0322) (0.0165) (0.0159) (0.0227) (0.0202) (0.0078) (0.0180)
Mean	0.2456	0.1740	0.0362	0.0574	0.1879	0.1250	0.0184	0.0507	
Panel B: Medical Treatments									
In-utero	0.0264	0.0056	0.0106	0.0219	0.0075	0.0109	0.0009	0.0092	(0.0313) (0.0234) (0.0081) (0.0199) (0.0227) (0.0141) (0.0025) (0.0175)
Mean	0.1829	0.0848	0.0035	0.0636	0.1700	0.0774	0.0022	0.0494	
N	1,116	1,116	1,116	1,116	2,237	2,237	2,237	2,237	

Table 1 The impact of in-utero radiation fear at age two and five

Exposing to radiation fear in the first trimester has the greatest impact

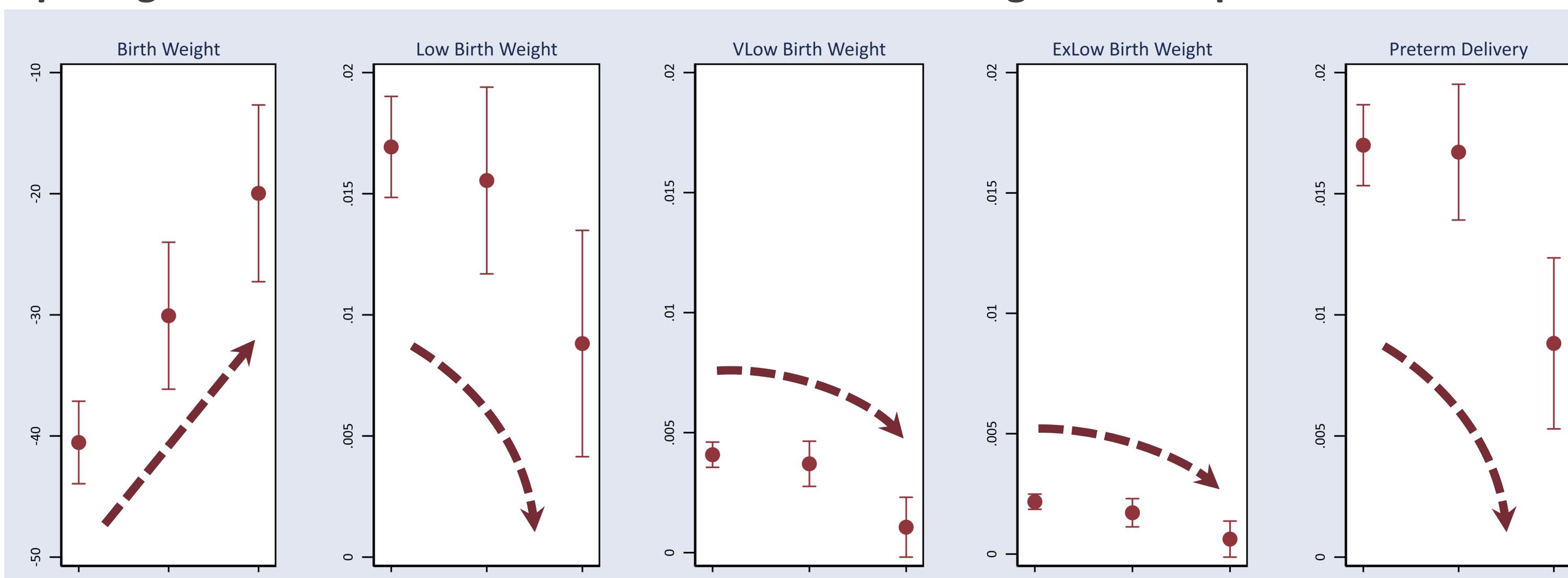


Fig. 7 The trimester-specific impact on birth outcomes

Underestimate the costs of intangible risks

- ◆ Not only the actual damage of the risks
- ◆ But also the fear of them can be harmful

Hidden costs of initial outbreaks of COVID-19

- ◆ The impact of maternal stress from infections

“Fear wisely!”

- ◆ Timely information sharing
- ◆ Efficient risk communication
- ◆ Education about radiation risks



Contact

Rong Fu, Waseda University, Japan

Email: nataliefu@waseda.jp

Website: <https://sites.google.com/view/nataliefu-homepage>



Full Paper



Website