경제학석사 학위논문

The Effect of In-Utero Exposure to the Covid-19 Pandemic

- Evidence from South Korea -

코로나19 대규모 감염사태와 출생결과: 한국의 사례를 중심으로

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경제학부

정 수 아

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The Effect of In-Utero Exposure to the Covid-19 Pandemic: Evidence from South Korea

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Abstract

The fact that the prenatal environment affects a person's human capital formation over a lifetime is widely known. Natural experiments, using events such as natural disasters, wars, terror attacks, and the spread of influenza as exogenous shocks, have been conducted to explore the effect of exposure to negative incidents during pregnancy on birth outcomes. This paper examines the effect of the spread of Covid-19 in Korea on the birth outcomes by applying difference-in-difference method to the Vital Statistics of 2019 and 2020. The birth weight of those who spent the second trimester of pregnancy in Daegu have decreased, but those who spent the first trimester showed improvement in LBW probability and preterm birth probability. The negative effects of the pandemic were stronger in the population with low socioeconomic status. The birth weight of those whose father is an elementary worker decreased with a greater magnitude, when exposed during their second trimester. They were also more likely to be low birth weight.

Keywords: Covid-19, fetal origins hypothesis, birth outcome, socioeconomic disparity

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Contents

1. Introduction

It is well known that negative in-utero exposures not only effect birth outcomes but can also lead to adverse consequences in the long-term, and is therefore crucial in a person's life. In economics, empirical studies use exogenous, traumatic events such as natural disasters, war or armed conflicts, terrorist attacks and pandemics as opportunities to capture such correlation since they provide a setting for natural experiment.

This paper uses the recent pandemic as a chance to explore and gain further evidence on the effect of in-utero exposure. The SARS-CoV-2 virus (hereinafter referred to as Covid-19), which broke out in Wuhan, China in December 2019, quickly spread to nearby countries and soon became a global phenomenon. South Korea was the second country to suffer from the pandemic, and therefore had to pioneer its way through uncertainty and chaos. The first wave of Covid-19 in Korea was highly concentrated in the city of Daegu, which provides an opportunity for semi-experimental study. This research hypothesizes that the social crisis induced by epidemic negatively affected fetal health of newborn babies. Using the Vital Statistics of 2019 and 2020, difference-in-difference method is applied to verify the hypothesis.

The results of this study suggest that despite some contrasting results, the rapid spread of Covid-19 negatively affected birth outcomes, especially in terms of birth weight. Birth weight among the newborn population exposed during their second trimester decreased, but LBW probability and preterm birth probability showed improvement among those exposed in their first trimester. However, among the population with low socioeconomic status, the effect of the pandemic was more consistent and concrete. Birth weight decreased to a greater degree, and LBW risk also increased within those exposed during their second trimester. The overall outcome of this paper implies that the negative effect of the pandemic might have worsened social disparity in fetal health.

2. Background

2.1. Literature review

Ever since David J. Barker developed the fetal origins hypothesis(D. J. Barker, 1990; D. J. P. Barker, 1994), numerous studies have confirmed the importance of in-utero environments. Especially in the field of economics, there have been many quasi-experimental studies to establish the correlation between in-utero experiences and health, socioeconomic outcomes,

both immediate and long-term.

For example, Almond, Edlund, and Palme (2009) studies the effect of prenatal exposure to Chernobyl fallout; the impact of natural disasters such as cyclones(Karbownik & Wray, 2019) and earthquakes(Menclova & Stillman, 2020; Torche, 2011) are also examined; many researchers study the effect of maternal stress due to political instabilities such as terrorist attacks(Camacho, 2008), domestic uprisings(Lee, 2014b), armed conflicts(Tsujimoto & Kijima, 2020), war(Lee, 2014a), military coup(Aparicio Fenoll & González, 2021). There are studies providing evidence on epidemic situations as well. Almond and Mazumder (2005) and Almond (2006) uses the influenza pandemic in 1918 as a natural experiment to test Barker's fetal origins hypothesis. In Asia, the Asian flu(Kelly, 2011) and malaria in 1950s Taiwan(Shih & Lin, 2018) are examined. Great famines recorded in history were observed as well, and have been proved to have harmful impacts on health and socioeconomic outcomes(Guven, Hoang, Rahman, & Ulubaşoğlu, 2021; Neugebauer, Hoek, & Susser, 1999; Roseboom et al., 2001).

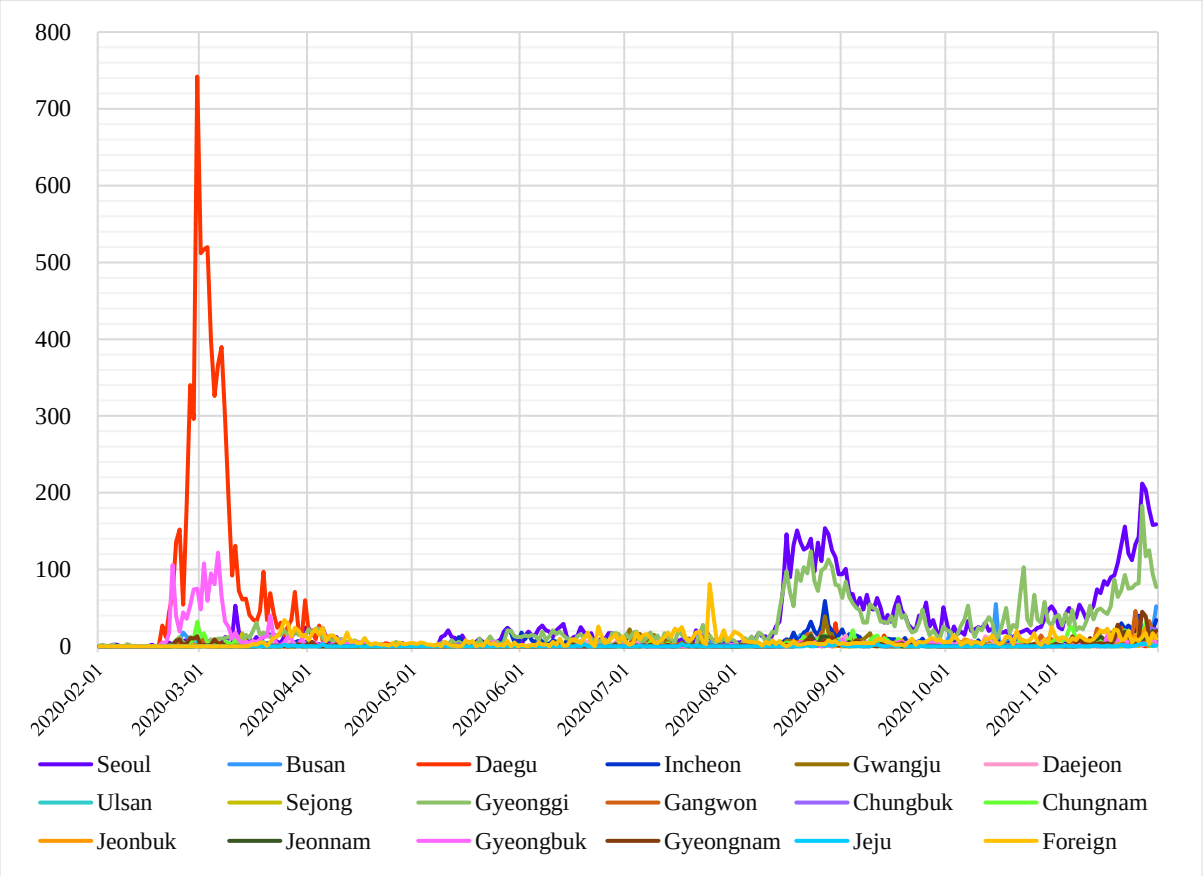
After Covid-19 broke out globally in 2020, there have been papers examining the effect of the pandemic on birth outcomes. Surprisingly, many studies around the world reported improved birth outcomes, mostly decrease in premature birth rates during lockdown(Berghella, Boelig, Roman, Burd, & Anderson, 2020; Caniglia et al., 2021; Hedermann et al., 2021; Meyer et al., 2021; Rolnik et al., 2021). Ranjbar et al. (2021) compared pre-Covid-19 births and intra-Covid-19 births and discovered that preterm births and low birth weight decreased during pandemic. Kim, Kim, Kil, and Lee (2021) performed a retrospective cohort study on infants born over a ten-year period in a single hospital in South Korea. They found that infants born preterm or with low birth weight markedly decreased during the pandemic period. Kirchengast and Hartmann (2021) compared births during lockdown and pre-lockdown in Austria and concluded that LBW rates were significantly lower in the lockdown phase.

2.2. Covid-19 in South Korea

The first confirmed case of Covid-19 in South Korea occurred on January 20th, 2020.(Choi, Kwon, & Lee, 2020) The disease barely spread until February 18th, when the mass infection among the members of Shincheonji Church of Jesus in Daegu started. On February 20th, the Korean government declared Daegu to be a 'Special Management Region' for contagious diseases.(Development Finance Bureau, 2020) On February 23rd, the Infectious Disease Risk Alert was raised from Level 3 to Level 4, which is the highest level.(Task Force for Tackling COVID-19, 2020) The cumulative number of confirmed cases were 30 before the mass outbreak, which sharply increased and reached 8652 by March 20th. During the 1st wave of Covid-19, the large majority of the patients were located in Daegu, where the cumulative

number of confirmed cases was 6275 on March 20th.

Figure 1. Number of confirmed cases of Covid-19 in South Korea (2020.02.01~2020.11.30)



*Data source: Ministry of Health and Welfare of South Korea

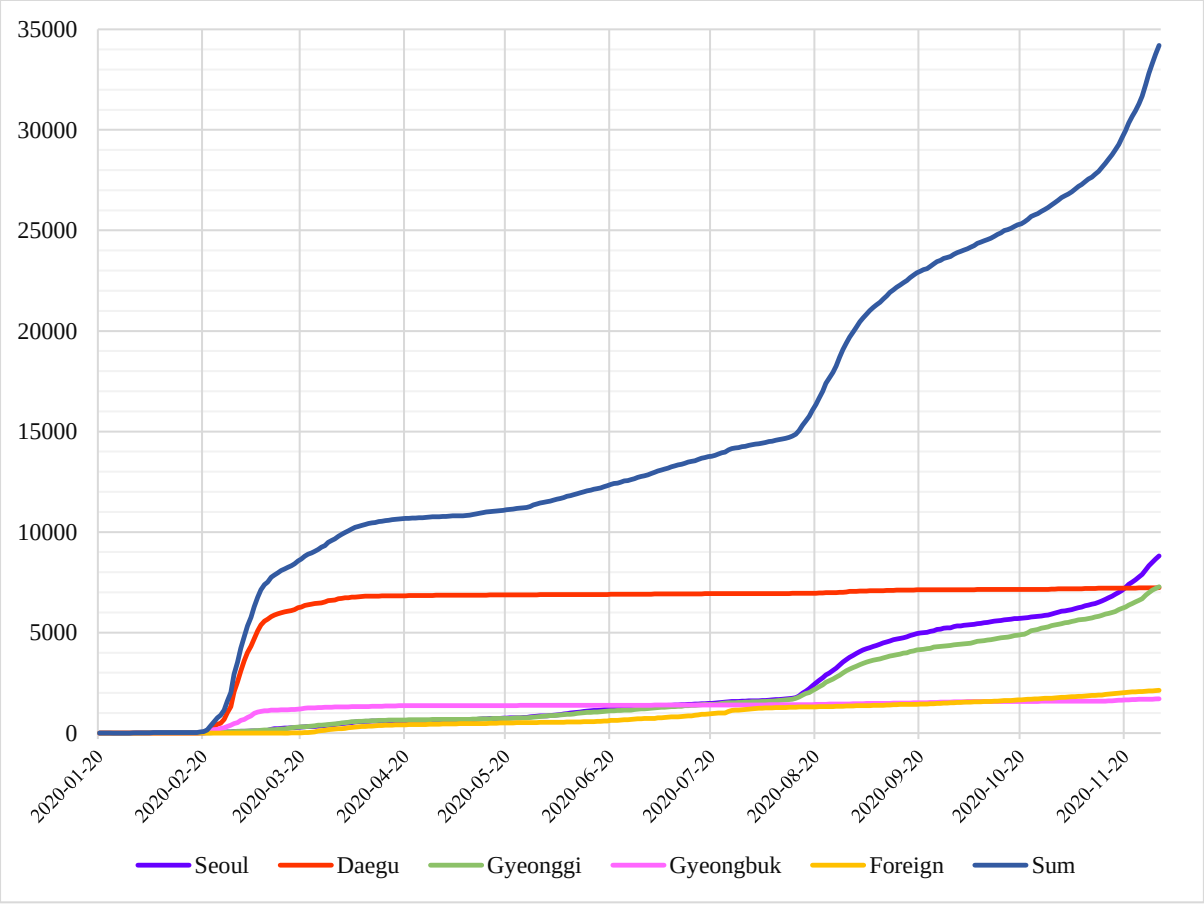
This incidence provides an opportunity to explore the fetal origins hypothesis due to the following reasons. First, the mass outbreak was completely unanticipated. Before February 18th of 2020, the number of daily confirmed cases of Covid-19 were less than 5. However, it suddenly reached 32 on February 19th, and continued to steeply increase since then. After Covid-19 first occurred and spread in China, South Korea was the second country in the world to experience the newfound disease become a national epidemic. Therefore, not much was known about Covid-19 at that time on a global level as well. It was an unprecedented type of disease, especially in terms of its powerful transmission rate.

Second, this mass infection of disease caused social unsettlement and confusion. Korean government's response systems in coping with Covid-19 were not settled at the beginning of the crisis. Online price of mask rose from 3300KRW to 4300KRW over the first week of the mass infection. Due to panic buying of masks, out-of-stock rates rapidly increased

as well.(Development Finance Bureau, 2020) It was not until after 12 days of the first confirmed case in Daegu that general public policies were implemented. Social distancing measures were introduced on February 29th, and mask stabilization policies were introduced on March 5th to deal with mask insufficiency.(Task Force for Tackling COVID-19, 2020)

Third, the incident was focused on a specific region. During the first wave of Covid-19, the confirmed cases were highly concentrated in Daegu and its nearby regions such as Cheongdo county in Gyeongbuk province. Since Daegu was the epicenter of the crisis, we can hypothesize that the socioeconomic and psychological effect of the 1st wave of Covid-19 were the strongest in Daegu. Thus, this incident provides a situation where natural experiment can be applied to explore the relationship between birth outcome and in-utero exposure to an epidemic crisis.

Figure 2. Number of cumulative confirmed cases of Covid-19 in South Korea (2020.01.20~2020.11.30)



*Data source: Ministry of Health and Welfare of South Korea

3. Data and Methods

This paper uses micro data of the 2019 and 2020 Vital Statistics for birth in South Korea. This data includes variables such as the child's birth weight, child's sex, length of gestation, and the date and place of birth. It also contains the age, level of education, occupation and nationality of the infant's parents.

As seen in Figure 1 and Figure 2, the 2nd wave of Covid-19, which started in mid-August of 2020, spread mainly in Seoul and Gyeonggi province. Therefore, the individuals born in Seoul and Gyeonggi province between September to November of 2020 were presumably affected by the 2nd wave. These observations were excluded from the data due to the possibility of contamination. Observations which had 0 as birth weight, and in which the parents' age, level of education, citizenship or nationality were unknown were also removed.

To analyze the effect of in-utero exposure to the 1st wave of Covid-19, the following difference-in-difference estimation is used:

$$y_i = b_0 + \sum_{j=1}^{3} b_{1j} * InUteroj_i + b_2 * Daegu_i + \sum_{j=1}^{3} b_{3j} * (InUteroj_i * Daegu_i) + a * X_i + \varepsilon_i$$

y_i denotes birth outcomes such as birth weight, LBW probability and preterm birth probability for individual i. When y_i represents LBW probability or preterm birth probability, I use the linear probability model for estimation. When examining low birth weight, y_i is a dummy variable which takes the value of 1 if the infant's birth weight was less than 2.5kg and 0 if otherwise. When analyzing preterm birth, y_i is a dummy variable which takes the value of 1 if the child was born before 37 weeks and 0 if otherwise.

$InUteroj_i$ is a dummy variable that takes the value of 1 if individual i was in their j th(j = 1,2,3) trimester during the first two weeks(2020.02.18~2020.03.02) of the mass infection and 0 if otherwise. Since the three trimesters of pregnancy are obtained by dividing the 42 weeks of pregnancy by three, the first trimester is 1~14 weeks, the second trimester is 15~28 weeks, and the third trimester is 29~42 weeks. The data only provides information about the child's birth year and month, and does not provide the exact birth date. Therefore, I assume the individuals born from September to November of 2020 to have been exposed during their 1st trimester. Children born between June and August of 2020 are considered to have been exposed during their 2nd trimester. Lastly, those born from March to May of 2020 are considered to have been exposed during their 3rd trimester.[1]

[1] If the trimester is not distinguished, the coefficient of the interaction term is not statistically significant. That is, regression analysis using a dummy variable that indicates whether the individual was in-utero during the first week of the 1st wave of Covid-19 instead of $InUteroj_i$ was not significant.

Table 1: Summary of variables (% or mean(sd))

Variable	Daegu, born 2020.03~11	Daegu, surrounding cohorts	Other regions, born 2020.03~11	Other regions, surrounding cohorts
Birth weight (g)	3156.2 (461.02)	3166 (467.555)	3172.7 (467.844)	3179.1 (473.835)
Length of gestation (week)	38.2 (1.976)	38.2 (2.351)	38.2 (2.176)	38.3 (2.227)
Sex				
... Female	48.6%	48%	48.7%	48.7%
... Male	51.4%	52%	51.3%	51.3%
Twin				
... Triplets or more	0.1%	0.1%	0.1%	0.1%
... Twin	3.7%	3.5%	4.7%	4.6%
... Singleton	96.2%	96.5%	95.2%	95.2%
Father's occupation				
... Unknown or armed forces	4.6%	4.9%	6.4%	6%
... Student, homemaker or jobless	10.2%	8.7%	9.1%	8%
... Elementary workers	13.1%	13.2%	10.5%	10.6%
... Plant, machine operators and assemblers	8.6%	8.1%	8.3%	7.8%
... Craft and related trades worker	4.9%	5.4%	5.3%	5.2%
... Agricultural, forestry and fishery workers	0.2%	0.2%	0.5%	0.5%
... Service or sales workers	14.1%	14.4%	11.5%	12.2%
... Clerks	17.3%	17.9%	19.5%	20.1%
... Professionals and related workers	20%	19.9%	21.5%	21.6%
... Managers	7.1%	7.3%	7.6%	8%
Father's education				
... College or higher	80%	80%	77.2%	77.7%
... High school	19%	18.9%	21.6%	21.2%
... Middle school or less	1%	1%	1.2%	1.2%
Father's age	35.7 (4.685)	35.2 (4.724)	35.8 (4.942)	35.3 (4.872)
Father's citizenship				
... Foreigner	1%	0.9%	1%	1.1%
... Korean (naturalized)	0.1%	0%	0.2%	0.2%
... Korean (birth)	98.9%	99.1%	98.8%	98.7%
Mother's occupation				
... Unknown or armed forces	2.5%	2.5%	3.5%	3.4%
... Student, homemaker or jobless	42.9%	45.2%	40.5%	43%
... Elementary workers	3.6%	3.5%	2.9%	3.6%
... Plant, machine operators and assemblers	1.5%	1.6%	1.9%	1.8%
... Craft and related trades worker	0.5%	0.4%	0.6%	0.6%
... Agricultural, forestry and fishery workers	0.1%	0%	0.1%	0.2%
... Service or sales workers	11.5%	10.1%	10.7%	9.9%
... Clerks	16.1%	17.4%	18.8%	18.6%
... Professionals and related workers	19.5%	17.7%	18.6%	16.6%
... Managers	1.8%	1.5%	2.3%	2.4%
Mother's education				
... College or higher	83.4%	83.8%	80.2%	80.2%
... High school	15.1%	14.8%	18.3%	18.3%
... Middle school or less	1.5%	1.4%	1.5%	1.5%
Mother's age	33(4.298)	32.5(4.241)	33.1(4.326)	32.6(4.315)
Mother's citizenship				
... Foreigner	3.6%	3.4%	4.1%	3.8%
... Korean (naturalized)	0.8%	0.9%	0.9%	1%
... Korean (birth)	95.6%	95.7%	95%	95.1%

$Daegu_i$ is a dummy variable which takes the value of 1 if individual i was born in Daegu and 0 if otherwise; X_i represents other characteristics of the observation i such as the infant's sex, birth month, length of gestation (in week), twin, and the parents' age, level of education, occupation and citizenship. Polynomial terms of the mother's age (mother's age, mother's age^2) are included.

Table 1 shows the summary of independent and control variables by group. For the individuals born in Daegu, birth weight is 3156.2g for those born from March to November, 2020, and 3166g for the surrounding cohorts. In other regions, it is 3172.7g and 3179.1g, respectively. Individuals born in Daegu had higher percentage of elementary workers as fathers compared to other regions.

4. Results

4.1. General analysis

Table 2, 3 and 4 show the effect of in-utero exposure to the 1st wave of Covid-19 on birth outcomes. Column (1) is the regression result without controlling any of the parent's SES. Column (2) is the result for only including variables that represent the mother's SES, and column (3) is when the father's SES is also controlled.

Table 2 presents the regression results for birth weight as the dependent variable. The coefficient of the interaction term between the dummy variable representing the birth in Daegu and the dummy variable for being born between June to August of 2020 is significant and is around -17. Thus, those who were exposed to the 1st wave of Covid-19 in their second trimester were negatively affected in terms of birth weight.

Table 3 shows outcomes for LBW probability, and Table 4 presents the regression analysis on preterm birth risk. No negative effect of the 1st wave of Covid-19 on low birth weight risk and preterm birth risk can be found. Rather, the coefficient of the interaction term between the dummy variable representing birth in Daegu and the dummy variable for being exposed to the incident during the 1st trimester is negative and significant for both dependent variables. Children who experienced the mass epidemic during the 1st trimester, were 0.9% less likely to be born below 2.5kg and 1.3% less likely to be born before 37 weeks of gestation. The result on low birth weight and preterm birth is supportive of preexisting studies on the effect of Covid-19 epidemic and lockdown policies on birth outcomes.

Table 2: Effect of 1st wave of Covid-19 on birth weight

	Weight (in gram)		
	(1)	(2)	(3)
3rd trimester	0.309	0.459	0.403
	(2.125)	(2.125)	(2.125)
2nd trimester	4.333**	4.557**	4.398**
	(2.186)	(2.186)	(2.186)
1st trimester	-2.712	-2.850	-3.216
	(2.696)	(2.695)	(2.697)
3rd trimester x Daegu	-1.260	-1.549	-1.721
	(8.244)	(8.240)	(8.239)
2nd trimester x Daegu	-16.722**	-17.129**	-17.079**
	(8.335)	(8.331)	(8.330)
1st trimester x Daegu	4.063	3.979	4.116
	(8.748)	(8.744)	(8.743)
Daegu	-18.682***	-18.240***	-18.413***
	(3.244)	(3.244)	(3.244)
Mother age	4,072.576***	5,211.458***	5,225.764***
	(398.443)	(409.878)	(411.612)
Mother age^2	-4,648.703***	-5,959.264***	-6,094.697***
	(396.665)	(416.644)	(418.542)
Male	103.686***	103.801***	103.779***
	(1.105)	(1.104)	(1.104)
Twin	428.365***	428.779***	428.740***
	(16.176)	(16.169)	(16.167)
Singleton	1,058.902***	1,058.056***	1,057.764***
	(16.033)	(16.026)	(16.024)
Length of gestation	78.970***	79.283***	79.340***
	(0.262)	(0.262)	(0.262)
Mother high school		3.815**	1.752
		(1.537)	(1.635)
Mother middle school or less		-24.641***	-25.713***
		(4.858)	(5.023)
Father high school			3.112**
			(1.526)
Father middle school or less			-12.549**
			(5.427)
Constant	-912.400***	-884.502***	-829.390***
	(18.215)	(18.667)	(19.715)
Birth month	Yes	Yes	Yes
Mother occupation and citizen	No	Yes	Yes
Father occupation and citizen	No	No	Yes
Observations	515,825	515,825	515,825
R^2	0.294	0.295	0.295
F Statistic	8,948.108*** (df = 24; 515800)	5,823.710*** (df = 37; 515787)	4,314.299*** (df = 50; 515774)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table 3: Effect of 1st wave of Covid-19 on LBW probability

	LBW		
	(1)	(2)	(3)
3rd trimester	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)
2nd trimester	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
1st trimester	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)
3rd trimester x Daegu	0.001	0.001	0.001
	(0.005)	(0.005)	(0.005)
2nd trimester x Daegu	0.004	0.004	0.004
	(0.005)	(0.005)	(0.005)
1st trimester x Daegu	-0.009*	-0.009*	-0.008*
	(0.005)	(0.005)	(0.005)
Daegu	0.006***	0.007***	0.007***
	(0.002)	(0.002)	(0.002)
Mother age	3.154***	3.662***	3.805***
	(0.219)	(0.225)	(0.226)
Mother age^2	3.665***	2.808***	2.643***
	(0.218)	(0.229)	(0.230)
Male	-0.012***	-0.011***	-0.011***
	(0.001)	(0.001)	(0.001)
Twin	-0.394***	-0.394***	-0.394***
	(0.009)	(0.009)	(0.009)
Singleton	-0.931***	-0.931***	-0.931***
	(0.009)	(0.009)	(0.009)
Mother high school		0.010***	0.008***
		(0.001)	(0.001)
Mother middle school or less		0.017***	0.012***
		(0.003)	(0.003)
Father high school			0.004***
			(0.001)
Father middle school or less			0.012***
			(0.003)
Constant	0.973***	0.973***	0.958***
	(0.009)	(0.009)	(0.010)
Birth month	Yes	Yes	Yes
Mother job and citizen	No	Yes	Yes
Father job and citizen	No	No	Yes
Observations	515,825	515,825	515,825
R^2	0.225	0.225	0.225
F Statistic	6,496.320*** (df = 23; 515801)	4,157.227*** (df = 36; 515788)	3,056.464*** (df = 49; 515775)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table 4: Effect of 1st wave of Covid-19 on preterm birth probability

	Preterm birth		
	(1)	(2)	(3)
3rd trimester	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)
2nd trimester	0.002	0.002	0.002
	(0.001)	(0.001)	(0.001)
1st trimester	0.004***	0.004**	0.003**
	(0.002)	(0.002)	(0.002)
3rd trimester x Daegu	0.001	0.001	0.001
	(0.005)	(0.005)	(0.005)
2nd trimester x Daegu	0.005	0.005	0.005
	(0.005)	(0.005)	(0.005)
1st trimester x Daegu	-0.013**	-0.013**	-0.012**
	(0.005)	(0.005)	(0.005)
Daegu	0.006***	0.007***	0.007***
	(0.002)	(0.002)	(0.002)
Mother age	3.786***	4.859***	5.053***
	(0.247)	(0.254)	(0.255)
Mother age^2	4.253***	2.530***	2.297***
	(0.246)	(0.259)	(0.260)
Male	0.012***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)
Twin	-0.365***	-0.364***	-0.365***
	(0.010)	(0.010)	(0.010)
Singleton	-0.940***	-0.939***	-0.940***
	(0.010)	(0.010)	(0.010)
Mother high school		0.017***	0.014***
		(0.001)	(0.001)
Mother middle school or less		0.022***	0.016***
		(0.003)	(0.003)
Father high school			0.005***
			(0.001)
Father middle school or less			0.014***
			(0.003)
Constant	0.985***	0.991***	0.992***
	(0.010)	(0.010)	(0.011)
Birth month	Yes	Yes	Yes
Mother job and citizen	No	Yes	Yes
Father job and citizen	No	No	Yes
Observations	515,825	515,825	515,825
R^2	0.206	0.207	0.207
F Statistic	5,818.669*** (df = 23; 515801)	3,735.616*** (df = 36; 515788)	2,747.795*** (df = 49; 515775)

Notes: *p<0.1; **p<0.05; ***p<0.01

There are many possible scenarios that could have lead to such results. First, selection bias due to inter-province migration may have occurred. Second, miscarriage or still-birth may have increased among women who were exposed to the mass outbreak during their 1st trimester. Third, these mothers and children may have been considered to be more vulnerable and received more support and investment from their family during pregnancy.

4.2. Subgroup analysis

Table 5, 6 and 7 show the results for a subgroup analysis – effect of in-utero exposure to the 1st wave of Covid-19 on children whose father is elementary worker.[2] Column (1) is the regression result without controlling any of the parent's socioeconomic characteristics. Column (2) is the result for including only the variables that represent the mother's socioeconomic status, and column (3) is when both parents' socioeconomic characteristics are controlled.

Table 5 presents the regression results for birth weight as the dependent variable. The coefficient of the interaction term between the dummy variable for being born in Daegu and the dummy variable for being exposed during one's second trimester is negatively significant in all three models. Children born between June to August of 2020 in Daegu were about 52g lower in birth weight. Including parents' socioeconomic variables did not change the coefficient to a large degree. It is notable that the absolute value of the coefficient is about three times larger than the coefficient of the general analysis. Thus, the sudden, mass spread of Covid-19 had a comparably larger impact on those whose father is elementary worker than the whole cohort.

Table 6 reports outcomes for LBW probability. The coefficient of the interaction term between the dummy variable for being born in the 2nd trimester and being born in Daegu is positively significant in all three models. Controlling for parents' socioeconomic characteristics did not largely change the value of the coefficient. The output shows that experiencing the 1st wave of Covid-19 in the 2nd trimester increased LBW probability by 3%. This is a contrasting result compared to estimation of the entire group from Table 2, where the coefficient of interest

[2] Other various subgroup analyses were also done during the course of this research. For example, individuals whose father/mother's education level was middle school or less, mother's occupation was service or sales workers, or father/mother was a student, homemaker or jobless were separately examined. However, none of those analyses were statistically significant.

Table 5: Effect of 1st wave of Covid-19 on birth weight when father is elementary worker

	Weight		
	(1)	(2)	(3)
3rd trimester	2.236	2.537	2.547
	(6.966)	(6.967)	(6.967)
2nd trimester	-1.688	-0.927	-0.732
	(7.061)	(7.062)	(7.062)
1st trimester	-2.099	-1.434	-1.187
	(8.100)	(8.100)	(8.100)
3rd trimester x Daegu	32.421	31.690	31.703
	(24.726)	(24.714)	(24.713)
2nd trimester x Daegu	-51.274**	-52.422**	-52.420**
	(23.520)	(23.509)	(23.508)
1st trimester x Daegu	20.499	19.875	19.939
	(25.131)	(25.119)	(25.118)
Daegu	-19.125**	-17.716*	-17.563*
	(9.378)	(9.382)	(9.384)
Mother age	2,497.683***	2,972.011***	2,906.804***
	(414.990)	(431.301)	(432.362)
Mother age^2	-3,412.964***	-3,722.231***	-3,649.680***
	(413.609)	(431.270)	(432.425)
Male	98.193***	98.568***	98.409***
	(3.522)	(3.521)	(3.521)
Twin	555.150***	549.597***	548.149***
	(68.527)	(68.507)	(68.505)
Singleton	1,196.726***	1,189.577***	1,188.477***
	(68.132)	(68.113)	(68.110)
Length of gestation	76.858***	77.108***	77.066***
	(0.803)	(0.804)	(0.804)
Mother high school		-1.154	-0.922
		(4.005)	(4.190)
Mother middle school or less		-23.825**	-19.031*
		(10.479)	(10.766)
Father high school			1.298
			(3.844)
Father middle school or less			-23.152**
			(11.381)
Constant	-958.213***	-921.092***	-861.240***
	(73.074)	(74.151)	(77.611)
Birth month	Yes	Yes	Yes
Mother occupation and citizen	No	Yes	Yes
Father citizen	No	No	Yes
Observations	55,151	55,151	55,151
R^2	0.269	0.270	0.270
F Statistic	845.202*** (df = 24; 55126)	550.850*** (df = 37; 55113)	509.886*** (df = 40; 55110)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table 6: Effect of 1st wave of Covid-19 on LBW probability when father is elementary worker

	LBW		
	(1)	(2)	(3)
3rd trimester	-0.006	-0.006	-0.006*
	(0.004)	(0.004)	(0.004)
2nd trimester	0.002	0.002	0.002
	(0.004)	(0.004)	(0.004)
1st trimester	-0.005	-0.005	-0.005
	(0.004)	(0.004)	(0.004)
3rd trimester x Daegu	-0.002	-0.002	-0.002
	(0.013)	(0.013)	(0.013)
2nd trimester x Daegu	0.030**	0.031**	0.031**
	(0.012)	(0.012)	(0.012)
1st trimester x Daegu	0.005	0.005	0.005
	(0.013)	(0.013)	(0.013)
Daegu	-0.001	-0.001	-0.001
	(0.005)	(0.005)	(0.005)
Mother age	0.647***	0.412*	0.450**
	(0.216)	(0.225)	(0.225)
Mother age^2	0.864***	0.994***	0.957***
	(0.215)	(0.225)	(0.225)
Male	-0.016***	-0.016***	-0.016***
	(0.002)	(0.002)	(0.002)
Twin	-0.321***	-0.321***	-0.321***
	(0.036)	(0.036)	(0.036)
Singleton	-0.760***	-0.759***	-0.759***
	(0.035)	(0.035)	(0.035)
Length of gestation	-0.034***	-0.034***	-0.034***
	(0.000)	(0.000)	(0.000)
Mother high school		0.005**	0.004*
		(0.002)	(0.002)
Mother middle school or less		0.002	-0.000
		(0.005)	(0.006)
Father high school			0.004**
			(0.002)
Father middle school or less			0.005
			(0.006)
Constant	2.110***	2.094***	2.078***
	(0.038)	(0.039)	(0.040)
Birth month	Yes	Yes	Yes
Mother occupation and citizen	No	Yes	Yes
Father citizen	No	No	Yes
Observations	55,151	55,151	55,151
R^2	0.280	0.280	0.280
F Statistic	891.470*** (df = 24; 55126)	580.393*** (df = 37; 55113)	537.055*** (df = 40; 55110)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table 7: Effect of 1st wave of Covid-19 on preterm birth probability when father is elementary worker

	Preterm birth		
	(1)	(2)	(3)
3rd trimester	0.000	0.000	-0.000
	(0.004)	(0.004)	(0.004)
2nd trimester	0.009**	0.009**	0.009**
	(0.004)	(0.004)	(0.004)
1st trimester	0.009*	0.009*	0.009*
	(0.005)	(0.005)	(0.005)
3rd trimester x Daegu	-0.017	-0.017	-0.017
	(0.016)	(0.016)	(0.016)
2nd trimester x Daegu	0.010	0.010	0.010
	(0.015)	(0.015)	(0.015)
1st trimester x Daegu	-0.024	-0.025	-0.025
	(0.016)	(0.016)	(0.016)
Daegu	0.009	0.011*	0.011*
	(0.006)	(0.006)	(0.006)
Mother age	1.959***	2.385***	2.427***
	(0.261)	(0.271)	(0.272)
Mother age^2	1.610***	1.021***	0.975***
	(0.261)	(0.272)	(0.273)
Male	0.012***	0.012***	0.012***
	(0.002)	(0.002)	(0.002)
Twin	-0.342***	-0.342***	-0.341***
	(0.043)	(0.043)	(0.043)
Singleton	-0.933***	-0.934***	-0.933***
	(0.043)	(0.043)	(0.043)
Mother high school		0.019***	0.019***
		(0.003)	(0.003)
Mother middle school or less		0.019***	0.016**
		(0.007)	(0.007)
Father high school			-0.000
			(0.002)
Father middle school or less			0.012*
			(0.007)
Constant	0.987***	0.988***	0.949***
	(0.043)	(0.044)	(0.046)
Birth month	Yes	Yes	Yes
Mother job and citizen	No	Yes	Yes
Father citizen	No	No	Yes
Observations	55,151	55,151	55,151
R^2	0.181	0.182	0.182
F Statistic	528.735*** (df = 23; 55127)	340.601*** (df = 36; 55114)	314.701*** (df = 39; 55111)

Notes: *p<0.1; **p<0.05; ***p<0.01

was negatively significant.[3] Along with the difference in estimation for birth weight, this outcome implies that the elementary workers were more vulnerable to the exogenous shocks caused by the spread of Covid-19.

Table 7 presents regression outcomes for subgroup analysis on preterm birth risk. Coefficients of dummy variables representing 1st and 2nd trimester are both positive and significant. Coefficient of the dummy variable indicating birth in Daegu is also positive and significant when parents' socioeconomic characteristics are controlled. However, none of the coefficients for the interaction term between dummy variables standing for birth trimester and the dummy variable indicating birth in Daegu is statistically significant. This is a contrasting result compared to the outcomes for general analyses shown in Table 4. It is also inconsistent with the majority of preexisting studies which reported a decrease in preterm birth rates during lockdown due to Covid-19.

4.3. Robustness check

The following regressions are conducted to check robustness. The estimation results can be found in the appendix.

The first two versions of robustness checks are done to clarify the region of influence. During the 1st wave of Covid-19, Daegu's nearby regions were affected by the incident as well. Especially Cheongdo, a county in Gyeongbuk, was declared 'Special Management Region' along with Daegu due to the mass infection in the Daenam hospital(Development Finance Bureau, 2020). Although smaller in magnitude, it can be assumed that Gyeongbuk was also negatively impacted by the 1st wave of Covid-19 since Gyeongbuk was the second region to have many confirmed cases.

First, individuals born in Gyeongbuk are removed. Coefficients of interest for birth weight did not change much in value or significance. Infants who were born in Daegu and experienced the 1st wave of Covid-19 in their 2nd trimester were about 16 grams lower in birth weight, with parents' socioeconomic factors controlled. For children whose father is an elementary worker, the birth weight is about 51 grams lower. Results are also similar for other dependent variables - LBW probability and preterm birth probability. Table A1 and A2 show the outcomes for this regression.

[3] In addition, regression results for the subgroup analysis for those whose father is an elementary worker are more concrete and consistent compared to the analysis on the entire group. The coefficient of interest in the estimation for the entire group was only significant when length of gestation was not controlled. In contrast, in the subgroup analysis on individuals whose father is an elementary worker, the coefficient of interest was significant regardless of controlling for length of gestation.

Second, the dummy variable representing birth in Daegu is replaced with a dummy variable presenting birth in Daegu or Gyeongbuk. Coefficients of interest for birth weight is no longer significant when the alternative variable is used instead. Table A3 and A4 show the results for this estimation. These two robustness tests show that individuals born in Gyeongbuk are not a homogeneous group with those born in Daegu, and thus negative effects of the mass epidemic was concentrated in Daegu.

Third, DID estimation is conducted on the same setting but with extended data. Micro data of 2017 to 2020 Vital Statistics is used. Table A5 show the outcomes for the entire group. Coefficients for the interaction term between dummy variables for being born in the 2nd trimester and being born in Daegu is negatively significant for birth weight. The absolute value of this coefficient is larger than in the general analysis, reporting -22.109. Coefficient of interest for LBW probability is not significant, whereas preterm birth probability is lowered by 1.1% for those who were exposed during their second trimester and was born in Daegu. Estimation results on those whose father is an elementary worker can be found in Table A6. Coefficient of interest for birth weight is also negatively significant but slightly larger in magnitude compared to the main results, showing -58.341 for those born in Daegu and exposed during their second trimester. LBW probability is increased by 3.1% in the same group, and coefficients of interest for preterm birth probability is not significant.

Lastly, placebo test is conducted using the micro data of Vital Statistics of 2017 and 2018. The results can be found in Table A7 and A8 in the appendix. None of the coefficients of interest for birth weight and preterm birth probability are significant in both analyses. Those born between September and November of 2018 in Daegu had lower LBW probability, 0.6% lower in the whole group and 2.2% lower for those whose father is an elementary worker.

5. Conclusions

According to the fetal origins hypothesis, in-utero environment is crucial in terms of birth outcomes and also in life later on. Exposure to a harmful event during pregnancy can have life-long negative impacts. The rapid spread of Covid-19 in South Korea when the disease was emerging as a world pandemic was an extremely stressful situation. The disease was highly infectious and lead to almost 10,000 confirmed cases by the end of March, 2020. It was an unprecedented situation, and the South Korean society was full of panic during those first few months of epidemic.

This paper provides evidence that massive Covid-19 outbreak situation damaged fetal health in terms of birth weight, and that its effect was more severe among the socioeconomically disadvantaged population. Using 2019-2020 Vital Statistics and difference-in-difference method, this paper finds that this incident lowered birth weight by 17g among those exposed during their second trimester. Though LBW birth rates decreased by 0.8% within

those exposed during their first semester and premature birth rates by 1.3%, this result is consistent with previous studies which reported declines in LBW rates and preterm birth rates regarding the effect of the pandemic and social distancing policies. It is notable that families with lower socioeconomic status were more affected. In the subgroup analysis to examine heterogeneity, the birth weight of children whose fathers are elementary workers were found to be about 52g reduced, when exposed during their second trimester. The same group were 3% higher in LBW probability. Preterm birth rates showed no significance. These findings show that the magnitude of the adverse effect was greater among children with lower socioeconomic status, implying that policy support might be necessary for this group later on.

Further studies covering the following topics are necessary in the future. First, contrasting results among difference indexes of birth outcomes should be dealt with, since birth weight decreased but LBW rates and preterm birth rates showed improvement in the whole group. In addition, in-depth research on the main cause of the impact of the sudden, mass infection of Covid-19 is needed. The spread of the disease affects the people through diverse channels. Unemployment and economic shocks could have directly affected birth outcomes. On the other hand, maternal stress due to various uncertain situations brought by the disease could have played a major role. Social distancing measures might have induced lack of prenatal care. The exact mechanism of these change in birth outcome during the pandemic period remains to be known.

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Table A1: Effect of 1st wave of Covid-19 on birth outcomes (exclude Gyeongbuk)

	Weight (in gram)	LBW	Preterm birth
3rd trimester	-1.177	-0.003	0.000
	(8.167)	(0.004)	(0.005)
2nd trimester	-12.653	0.005	0.007
	(8.263)	(0.005)	(0.005)
1st trimester	0.900	-0.008*	-0.009*
	(8.532)	(0.005)	(0.005)
3rd trimester x Daegu	-1.541	0.000	0.000
	(8.247)	(0.005)	(0.005)
2nd trimester x Daegu	-16.265*	0.003	0.005
	(8.338)	(0.005)	(0.005)
1st trimester x Daegu	4.576	-0.008*	-0.012**
	(8.775)	(0.005)	(0.005)
Daegu	-19.139***	0.007***	0.007***
	(3.248)	(0.002)	(0.002)
Mother age	5,135.367***	3.642***	4.844***
	(411.358)	(0.226)	(0.255)
Mother age^2	-5,820.261***	2.563***	2.257***
	(418.445)	(0.230)	(0.260)
Male	103.918***	-0.011***	0.012***
	(1.134)	(0.001)	(0.001)
Twin	438.112***	-0.395***	-0.367***
	(16.450)	(0.009)	(0.010)
Singleton	1,066.718***	-0.930***	-0.940***
	(16.305)	(0.009)	(0.010)
Length of gestation	79.115***		
	(0.269)		
Mother high school	1.460	0.008***	0.014***
	(1.687)	(0.001)	(0.001)
Mother middle school or less	-29.292***	0.013***	0.017***
	(5.220)	(0.003)	(0.003)
Father high school	4.069***	0.004***	0.005***
	(1.574)	(0.001)	(0.001)
Father middle school or less	-9.967*	0.012***	0.013***
	(5.608)	(0.003)	(0.003)
Constant	-849.763***	0.964***	0.999***
	(20.347)	(0.010)	(0.011)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father job and citizen	Yes	Yes	Yes
Observations	489,172	489,172	489,172
R^2	0.296	0.226	0.208
F Statistic	4,106.078*** (df = 50; 489121)	2,916.983*** (df = 49; 489122)	2,615.203*** (df = 49; 489122)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A2: Effect on birth outcomes when father is elementary worker (exclude Gyeongbuk)

	Weight	LBW	Preterm birth
3rd trimester	35.927	-0.008	-0.018
	(24.484)	(0.013)	(0.015)
2nd trimester	-54.475**	0.033***	0.019
	(23.282)	(0.012)	(0.015)
1st trimester	18.058	0.001	-0.015
	(24.598)	(0.013)	(0.015)
3rd trimester x Daegu	30.994	-0.003	-0.019
	(24.814)	(0.013)	(0.016)
2nd trimester x Daegu	-51.526**	0.030**	0.010
	(23.609)	(0.012)	(0.015)
1st trimester x Daegu	18.341	0.005	-0.021
	(25.282)	(0.013)	(0.016)
Daegu	-18.278*	-0.000	0.010*
	(9.424)	(0.005)	(0.006)
Mother age	3,021.203***	0.390*	2.248***
	(432.877)	(0.224)	(0.272)
Mother age^2	-3,497.020***	0.948***	0.968***
	(433.346)	(0.224)	(0.272)
Male	97.557***	-0.016***	0.012***
	(3.663)	(0.002)	(0.002)
Twin	551.167***	-0.319***	-0.335***
	(68.689)	(0.036)	(0.043)
Singleton	1,197.671***	-0.764***	-0.933***
	(68.260)	(0.035)	(0.043)
Length of gestation	75.640***	-0.033***	
	(0.830)	(0.000)	
Mother high school	-0.850	0.004*	0.020***
	(4.367)	(0.002)	(0.003)
Mother middle school or less	-22.906**	0.001	0.018**
	(11.221)	(0.006)	(0.007)
Father high school	1.670	0.005**	-0.000
	(4.004)	(0.002)	(0.003)
Father middle school or less	-22.609*	0.005	0.010
	(11.837)	(0.006)	(0.007)
Constant	-830.476***	2.048***	0.962***
	(78.609)	(0.041)	(0.046)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father citizen	Yes	Yes	Yes
Observations	51,155	51,155	51,155
R^2	0.269	0.283	0.185
F Statistic	469.434*** (df = 40; 51114)	503.891*** (df = 40; 51114)	297.719*** (df = 39; 51115)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A3: Effect of 1st wave of Covid-19 on birth outcomes (Daegu and Gyeongbuk)

	Weight (in gram)	LBW	Preterm birth
3rd trimester	0.254	-0.003***	0.000
	(2.161)	(0.001)	(0.001)
2nd trimester	3.683*	0.001	0.002
	(2.221)	(0.001)	(0.001)
1st trimester	-3.617	0.000	0.003*
	(2.800)	(0.002)	(0.002)
3rd trimester x Daegu+	1.114	-0.002	-0.005
	(5.772)	(0.003)	(0.004)
2nd trimester x Daegu+	-0.463	-0.001	-0.002
	(5.917)	(0.003)	(0.004)
1st trimester x Daegu+	7.905	-0.006*	-0.007*
	(6.218)	(0.003)	(0.004)
Daegu+	-16.488***	0.008***	0.007***
	(2.298)	(0.001)	(0.001)
Mother age	5,177.909***	3.828***	5.070***
	(411.671)	(0.226)	(0.255)
Mother age^2	-6,096.341***	2.644***	2.297***
	(418.539)	(0.230)	(0.260)
Male	103.765***	-0.011***	0.012***
	(1.104)	(0.001)	(0.001)
Twin	428.824***	-0.394***	-0.365***
	(16.167)	(0.009)	(0.010)
Singleton	1,057.940***	-0.931***	-0.940***
	(16.024)	(0.009)	(0.010)
Length of gestation	79.328***		
	(0.262)		
Mother high school	1.892	0.008***	0.014***
	(1.635)	(0.001)	(0.001)
Mother middle school or less	-25.459***	0.012***	0.016***
	(5.023)	(0.003)	(0.003)
Father high school	3.143**	0.004***	0.005***
	(1.526)	(0.001)	(0.001)
Father middle school or less	-12.540**	0.012***	0.014***
	(5.427)	(0.003)	(0.003)
Constant	-828.722***	0.958***	0.992***
	(19.716)	(0.010)	(0.011)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father job and citizen	Yes	Yes	Yes
Observations	515,825	515,825	515,825
R^2	0.295	0.225	0.207
F Statistic	4,314.522*** (df = 50; 515774)	3,057.170*** (df = 49; 515775)	2,747.947*** (df = 49; 515775)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A4: Effect on birth outcomes when father is elementary worker (Daegu and Gyeongbuk)

	Weight (in gram)	LBW	Preterm birth
3rd trimester	3.519	-0.005	0.001
	(7.149)	(0.004)	(0.005)
2nd trimester	-1.685	0.002	0.009**
	(7.237)	(0.004)	(0.005)
1st trimester	0.475	-0.005	0.005
	(8.447)	(0.004)	(0.005)
3rd trimester x Daegu+	5.680	-0.008	-0.020*
	(16.755)	(0.009)	(0.011)
2nd trimester x Daegu+	-16.479	0.008	0.005
	(16.497)	(0.009)	(0.010)
1st trimester x Daegu+	1.194	0.001	0.012
	(17.536)	(0.009)	(0.011)
Daegu+	-13.280**	0.003	0.002
	(6.464)	(0.003)	(0.004)
Mother age	2,889.696***	0.456**	2.427***
	(432.425)	(0.225)	(0.272)
Mother age^2	-3,651.987***	0.960***	0.973***
	(432.464)	(0.225)	(0.273)
Male	98.363***	-0.016***	0.012***
	(3.521)	(0.002)	(0.002)
Twin	549.416***	-0.321***	-0.341***
	(68.508)	(0.036)	(0.043)
Singleton	1,189.548***	-0.759***	-0.933***
	(68.114)	(0.035)	(0.043)
Length of gestation	77.072***	-0.034***	
	(0.804)	(0.000)	
Mother high school	-0.751	0.004*	0.019***
	(4.189)	(0.002)	(0.003)
Mother middle school or less	-18.951*	-0.000	0.016**
	(10.767)	(0.006)	(0.007)
Father high school	1.324	0.004**	-0.000
	(3.844)	(0.002)	(0.002)
Father middle school or less	-23.009**	0.005	0.012*
	(11.381)	(0.006)	(0.007)
Constant	-862.730***	2.078***	0.950***
	(77.615)	(0.040)	(0.046)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father job and citizen	Yes	Yes	Yes
Observations	55,151	55,151	55,151
R^2	0.270	0.280	0.182
F Statistic	509.695*** (df = 40; 55110)	536.923*** (df = 40; 55110)	314.679*** (df = 39; 55111)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A5: Effect of 1st wave of Covid-19 on birth outcomes (extended data)

	Weight	LBW	Preterm birth
3rd trimester	3.539	-0.003**	-0.003*
	(2.528)	(0.001)	(0.002)
2nd trimester	5.157**	-0.001	-0.002
	(2.556)	(0.001)	(0.002)
1st trimester	0.707	-0.000	0.001
	(3.002)	(0.002)	(0.002)
3rd trimester x Daegu	-6.362	0.002	0.002
	(7.767)	(0.004)	(0.005)
2nd trimester x Daegu	-22.109***	0.005	0.007
	(7.863)	(0.004)	(0.005)
1st trimester x Daegu	-1.362	-0.007	-0.011**
	(8.295)	(0.005)	(0.005)
Daegu	-13.263***	0.005***	0.005***
	(1.897)	(0.001)	(0.001)
Mother age	10,262.650***	5.223***	7.137***
	(408.839)	(0.223)	(0.251)
Mother age^2	-8,410.470***	3.771***	3.941***
	(414.705)	(0.227)	(0.255)
Male	105.371***	-0.011***	0.012***
	(0.726)	(0.000)	(0.000)
Twin	399.513***	-0.398***	-0.368***
	(11.194)	(0.006)	(0.007)
Singleton	1,006.318***	-0.935***	-0.942***
	(11.100)	(0.006)	(0.007)
Length of gestation	86.957***		
	(0.180)		
Mother high school	3.056***	0.007***	0.012***
	(1.061)	(0.001)	(0.001)
Mother middle school or less	-28.855***	0.015***	0.016***
	(3.341)	(0.002)	(0.002)
Father high school	0.886	0.004***	0.007***
	(1.003)	(0.001)	(0.001)
Father middle school or less	-12.841***	0.010***	0.010***
	(3.535)	(0.002)	(0.002)
Constant	-1,065.857***	0.961***	0.988***
	(13.480)	(0.007)	(0.007)
Birth year and month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father job and citizen	Yes	Yes	Yes
Observations	1,180,641	1,180,641	1,180,641
R^2	0.299	0.216	0.198
F Statistic	9,493.870*** (df = 53; 1180587)	6,257.923*** (df = 52; 1180588)	5,617.359*** (df = 52; 1180588)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A6: Effect on birth outcomes when father is elementary worker (extended data)

	Weight	LBW	Preterm birth
3rd trimester	-7.147	0.001	0.001
	(8.569)	(0.004)	(0.005)
2nd trimester	-2.397	0.007	0.004
	(8.605)	(0.004)	(0.005)
1st trimester	-11.903	0.006	0.005
	(9.488)	(0.005)	(0.006)
3rd trimester x Daegu	25.072	-0.001	-0.007
	(23.752)	(0.012)	(0.015)
2nd trimester x Daegu	-58.341***	0.031***	0.019
	(22.495)	(0.012)	(0.014)
1st trimester x Daegu	13.470	0.006	-0.015
	(24.172)	(0.012)	(0.015)
Daegu	-11.549*	-0.002	0.001
	(6.463)	(0.003)	(0.004)
Mother age	3,762.595***	0.491**	2.740***
	(432.352)	(0.222)	(0.269)
Mother age^2	-3,886.325***	1.176***	1.392***
	(430.867)	(0.221)	(0.269)
Male	99.593***	-0.016***	0.013***
	(2.645)	(0.001)	(0.002)
Twin	469.067***	-0.280***	-0.346***
	(42.939)	(0.022)	(0.027)
Singleton	1,108.070***	-0.720***	-0.936***
	(42.547)	(0.022)	(0.026)
Length of gestation	79.015***	-0.034***	
	(0.604)	(0.000)	
Mother high school	-2.972	0.003**	0.014***
	(3.118)	(0.002)	(0.002)
Mother middle school or less	-37.370***	0.010**	0.018***
	(7.813)	(0.004)	(0.005)
Father high school	-0.269	0.003**	0.004**
	(2.903)	(0.001)	(0.002)
Father middle school or less	-9.628	0.005	0.002
	(8.051)	(0.004)	(0.005)
Constant	-872.825***	2.074***	0.974***
	(55.786)	(0.029)	(0.033)
Birth year and month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father citizen	Yes	Yes	Yes
Observations	97,630	97,630	97,630
R^2	0.270	0.280	0.175
F Statistic	819.989*** (df = 44; 97585)	862.347*** (df = 44; 97585)	482.858*** (df = 43; 97586)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A7: Placebo test of general analysis (2017-2018 data)

	Weight	LBW	Preterm birth
3rd trimester	5.051***	-0.001	0.000
	(1.939)	(0.001)	(0.001)
2nd trimester	7.357***	-0.002**	-0.000
	(1.995)	(0.001)	(0.001)
1st trimester	5.134**	-0.001	0.002*
	(2.035)	(0.001)	(0.001)
3rd trimester x Daegu	5.861	-0.006*	-0.005
	(7.158)	(0.004)	(0.004)
2nd trimester x Daegu	-1.884	-0.005	-0.004
	(7.403)	(0.004)	(0.005)
1st trimester x Daegu	-9.047	-0.003	-0.006
	(7.605)	(0.004)	(0.005)
Daegu	-10.106***	0.006***	0.006***
	(2.901)	(0.002)	(0.002)
Mother age	9,122.196***	3.589***	5.072***
	(404.999)	(0.220)	(0.247)
Mother age^2	-5,615.357***	2.651***	3.182***
	(411.702)	(0.224)	(0.252)
Male	106.804***	-0.010***	0.011***
	(0.962)	(0.001)	(0.001)
Twin	371.307***	-0.402***	-0.371***
	(15.510)	(0.008)	(0.009)
Singleton	957.050***	-0.939***	-0.943***
	(15.383)	(0.008)	(0.009)
Length of gestation	93.934***		
	(0.247)		
Mother high school	4.058***	0.007***	0.011***
	(1.393)	(0.001)	(0.001)
Mother middle school or less	-31.331***	0.018***	0.015***
	(4.470)	(0.002)	(0.003)
Father high school	-0.556	0.005***	0.007***
	(1.331)	(0.001)	(0.001)
Father middle school or less	-12.902***	0.008***	0.008***
	(4.653)	(0.003)	(0.003)
Constant	-1,315.740***	0.969***	0.984***
	(19.289)	(0.010)	(0.011)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father job and citizen	Yes	Yes	Yes
Observations	664,816	664,816	664,816
R^2	0.303	0.209	0.191
F Statistic	5,566.755*** (df = 52; 664763)	3,435.779*** (df = 51; 664764)	3,078.194*** (df = 51; 664764)

Notes: *p<0.1; **p<0.05; ***p<0.01

Table A8: Placebo test of subgroup analysis (2017-2018 data)

	Weight	LBW	Preterm birth
3rd trimester	10.247	-0.014***	-0.014**
	(9.837)	(0.005)	(0.006)
2nd trimester	6.178	-0.010*	-0.013**
	(10.081)	(0.005)	(0.006)
1st trimester	9.110	0.001	-0.008
	(10.491)	(0.005)	(0.006)
3rd trimester x Daegu	0.313	-0.022*	-0.022
	(23.836)	(0.012)	(0.015)
2nd trimester x Daegu	18.957	-0.013	0.001
	(24.982)	(0.013)	(0.015)
1st trimester x Daegu	-21.617	-0.002	-0.005
	(24.309)	(0.012)	(0.015)
Daegu	-5.277	0.005	-0.002
	(14.191)	(0.007)	(0.009)
Mother age	2,390.006***	0.195	1.433***
	(430.770)	(0.218)	(0.264)
Mother age^2	-1,792.200***	0.673***	0.903***
	(429.561)	(0.217)	(0.264)
Male	101.184***	-0.015***	0.015***
	(4.010)	(0.002)	(0.002)
Twin	408.438***	-0.251***	-0.349***
	(55.355)	(0.028)	(0.034)
Singleton	1,046.889***	-0.695***	-0.934***
	(54.540)	(0.028)	(0.033)
Length of gestation	81.573***	-0.035***	
	(0.917)	(0.000)	
Mother high school	-5.653	0.003	0.008***
	(4.672)	(0.002)	(0.003)
Mother middle school or less	-57.696***	0.021***	0.020***
	(11.369)	(0.006)	(0.007)
Father high school	-2.557	0.001	0.009***
	(4.428)	(0.002)	(0.003)
Father middle school or less	4.270	0.005	-0.006
	(11.420)	(0.006)	(0.007)
Constant	-933.758***	2.070***	0.939***
	(72.219)	(0.037)	(0.040)
Birth month	Yes	Yes	Yes
Mother job and citizen	Yes	Yes	Yes
Father citizen	Yes	Yes	Yes
Observations	42,479	42,479	42,479
R^2	0.270	0.280	0.167
F Statistic	374.190*** (df = 42; 42436)	392.510*** (df = 42; 42436)	207.868*** (df = 41; 42437)

Notes: *p<0.1; **p<0.05; ***p<0.01

국문 초록

태아기 환경이 한 개인의 인적 자본 형성에 일생에 걸쳐 영향을 미친다는 사실은 경제학에서 널리 알려진 바다. 자연재해, 전쟁, 테러, 인플루엔자 확산 등의 외생적 충격이 발생한 사례를 활용해 태아기에 경험한 부정적 사건이 출생 결과 및 장기적인 사회경제적 성과에 미친 영향을 분석하는 많은 자연적 실험 연구가 그간 진행되어 왔다. 본 연구는 통계청의 인구동향조사를 사용하여 한국에서의 코로나19 확산이 출생 결과에 미친 영향을 살펴본다. 이중차분법을 활용해 분석한 결과, 대구에서 임신 2주기를 보낸 이들의 출생체중이 감소하였으나 임신 1주기를 보낸 이들은 저체중 출생 확률과 조산 확률이 낮아졌다. 팬데믹의 부정적 효과는 사회경제적 지위가 낮은 계층에서 더욱 두드러졌다. 아버지가 단순노무종사자인 경우, 대구에서 임신 2주기를 보낸 이들의 출생체중은 더 크게 감소했으며 저체중으로 태어날 확률 또한 높았다.

주요어: 코로나19, 태아기원가설, 출생결과, 사회경제적 불균형

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