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Do Older Mothers Deliver Smaller Babies?

: A Korean Study from an Economic Perspective

산모가 고령일수록 저체중아 출산 위험이 커지는가

: 한국에 대한 경제학 연구

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Abstract

Do Older Mothers Deliver Smaller Babies?
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The incidence of low birth weight(LBW) has increased since the 1990s in Korea and is now at an alarming level. This trend makes health professionals and policy-makers concerned because it imposes large costs on society in the short and long term. However, this trend is not expected since most birth weight determinants have changed in favor of increasing it. Using birth registration data, this study finds that increasing maternal age adversely affects birth outcomes, especially increasing the incidence of LBW. Specifically, advanced maternal age has a negative effect on gestational weeks and then the birth outcomes aggravate. Additionally, this study investigates why maternal age has a negative effect on gestational weeks. This study provides plausible explanation that the increasing incidences of subfertility and gestational diabetes with age account for deceasing gestational weeks. Low birth weight babies can be burden to individual and society in that the average hospital cost of low birth weight babies amounted to about 15 million won in 2016 and government's expenditure on policy of fundholding for LBW exceeded 11 billion won in 2016. Therefore, policies and campaigns that deal with pre/during-pregnancy maternal health status need to be implemented.

key words : LBW, Maternal age, Gestation weeks, Labor induction, Subfertility, Gestational diabetes
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Table of Contents

List of Tables

List of Figures

1. Introduction

Recently it is true that low birthrate itself is a serious problem in Korea, but the rate of preterm or low birth weight infants has reached alarming levels. The mean birth weight (BW) has declined significantly and the incidence of low birth weight has increased since the 1990s. Especially from 2002 to 2013, the mean birth weight dropped by 50 g and the incidence of low birth weight increased by 0.65 percentage points. These trends makes health professionals and policy-makers concerned.

Birth weight is used as the primary measure of health at birth and low birth weight (LBW) is conventionally defined as birth weight of less than 2,500 grams. Epidemiologists and health economists have found that the birth weight is not only an outcome of intrauterine nutritional intake, but is also a critical predictor of subsequent health status, cognitive development and socioeconomic status in adulthood (Barker 1990, 1995; Roseboom et al. 2006; Almond et al. 2005; Schulz 2010; Figlio et al. 2014). Also, increasing LBW can be seen as one of social problems. Infants born at low birth weight experience severe health and developmental difficulties that can impose substantial costs on society. For example, the expected costs of delivery and initial care of a baby weighing 1000 grams at birth can exceed $100,000 (in year 2000 dollars), and the risk of death within one year of birth is over one in five. Even among babies weighing 2000 - 2100 grams, who have comparatively low mortality rates, an additional pound (454 grams) of weight is still associated with a $10,000 difference in hospital charges for inpatient services (Almond et al. 2005). In the long term, a 10% increase in BW increases the probability of high school completion by a little less than 1 percentage point, is as valuable in the labor market as a quarter of a year of education, and raise full-time earinings by about 1% (Cock et al. 2015)

Notably, the most BW determinants have changed in favor of increasing it, but the birth outcomes have worsened. For example, many studies have found that the birth outcomes are positively associated with the maternal education level and parents' socioeconomic status. The percentage of mothers who completed more than a level of university education increased from 44% to 73% between 2002 and 2013. Additionally, the proportion of white collar workers among fathers increased about 1 percentage point. Taking these situations into consideration, increasing LBW is worthy of note.

It is our study's main objective to find which variable largely accounts for increasing LBW in Korea and find out the channel behind their relation. Also it is noteworthy to include induction rate as a BW determinant variable.

In order to address this question, this study use birth registration data and National Health Insurance Service (NHIS) data during 2002-2013. To address the endogeneity problem, this paper aggregate individual birth data into si-do group data.[1] This study finds that increase in maternal age explains about 87% of change in LBW. As mother gets one year older, gestational length (in weeks) is likely to decrease and birth outcomes get worse. Then, this correlation between maternal age and gestational weeks leads to one question: "Why gestational weeks decrease with age?" This paper suggests the increasing incidence of subfertility and gestational diabetes is the reason for decreasing gestational weeks.

This study also examines the effect of advanced maternal age on birth weight. Results suggests that birth weight is aslo negatively affected by maternal ages. Additionally, increasing ratio of labor induction has a negative effect on both LBW and birth weight.

The remainder of the paper is organized as follows. This paper will first discuss economic significance of increasing LBW, reviewing some of the related literature and then explains our method and data in section 3. Section 4 presents the estimation results for which variable significantly accounts for increasing LBW and section 5 tries to explain why gestational length decrease as maternal age goes up. Finally section 6 will summarize this study and give concluding remarks.

1) This study cannot completely solve the endogeneity problem, so it focuses on showing correlation between variables, not causality between them.

2. Economic Significance of Increasing LBW

A lot of studies have found that LBW is significant throughout the infant's lifetime as well as immediately after birth. The LBW infants tend to have lower educational attainment, poorer self-reported health status, and reduced employment and earnings as adults, relative to their normal weight counterparts.

Corman and Chaikind (1998) examined the school performance and behavior of children aged six to fifteen years who were born weighing less than 2500 g, compared with a group of normal birth weight children, holding constant socio-economic characteristics of the child and family. They found out that about 31% of low birth weight children repeat a grade by grade 10. comparing with about 26% of normal birth weight children. Additionally, low birth weight children are more likely to attend special education classes, even when holding constant the current health status of the child.

Behrman and Rosenzweig (2004) found that increasing fetal growth has a significant positive effect on schooling attainment, intrauterine nutrient intake significantly affects adult height, and augmenting birth weight among lower birth weight babies, but not among higher-birth weight babies, has significant labor market payoffs.

Stoll et al. (2005) conducted cohort study and concluded that the majority of LBW survivors have at least 1 infection during their hospitalization after birth. Compared with uninfected infants, those infant are significantly more likely to have adverse neurodevelopmental outcomes at follow-up, including cerebralpalsy (range of significant odds ratios[ORs], 1.4-1.7), low Bayley Scales of Infant Development II scores on the mental development index (ORs, 1.3-1.6) and psychomotor development index (ORs, 1.5-2.4), and vision impairment (ORs, 1.3-2.2).

Recent Studies have found that after controlling for confounding factors such as genetic factors or family background, the short-term effects of BW are not as large as what the cross-sectional estimates would suggest.

Almond et al. (2005) compared the hospital costs, health at birth, and infant mortality rates between heavier and lighter infants from all twin pairs born in the United States. The cross-sectional OLS estimates imply that a one standard deviation increase in birth weight is associated with a decrease in hospital costs, a reduction in infant mortality, an increase in APGAR scores, and a reduction in assisted ventilator use after birth, of 0.51, 0.41, 0.51, and 0.25 standard deviations, respectively. By contrast, controlling for mother-heterogeneity in the twins analysis, the corresponding magnitudes are 0.08, 0.03, 0.03, and 0.01. This study implied impacts of LBW that are many times smaller than those used in conventional cost-benefit calculations.

Similarly, Black et al. (2007) also found that twin fixed effects estimates of the effect of birth weight on short-run outcomes such as one-year infant mortality are much smaller than their cross-sectional equivalents. However, they found that birth weight has a significant effect on longer-run outcomes such as height, IQ at age 18, earnings, and education, and the fixed effects estimates are similar in size to cross-sectional ones. According to their estimates, a 10% increase in BW leads to a 57cm increase in height at 18, an approximately 1% increase in full-time earnings.

Most recently, Figlio et al. (2014) examined how poor neonatal health affects child development and later-lifer outcomes. They found that a 10% increase in BW is associated with a 0.045-standard-deviation increase in test scores and the cognitive advantage appears as early as at age five years and remains constant through the elementary and middle-school years. These results strongly point to the notion that the effects of poor neonatal health on adult outcomes are largely determined early - in early childhood and the first years of elementary school.

In Korea, the increasing of maternal age has been considered as an important contributor to the trends of birth outcomes. According to Park et al (2002), in the LBW infants group, proportion of old age mothers is significantly higher than those of the normal infant group. Additionally, Lee (2007) found out that advanced maternal age and poverty are key variables which have an adverse effect on birth outcomes.

3. Data and Method

To explain the increasing LBW, this study conducts a si-do level regression analysis. Suppose that LBW (or BW) is determined at the individual level by using the following function:

$$LBW_{ist} = \beta_o O_{ist} + \beta_x x_{ist} + \beta_z z_{ist} + \alpha_i + \lambda_s + \epsilon_{ist}$$

where the subscripts represent individual i, si-do s, year t. The dependent variable, LBW_{ist}, represents whether an infant is LBW or not. Vector O_{ist} represents whether use obstetric intervention (labor induction and Caesarean section) or not, x_{ist} comprises of parent's characteristics, including maternal age, maternal education level and father′s job. and z_{ist} is consist of birth outcomes such as gender of the infant, birth order, season at birth and gestation weeks. ϵ_{ist} is the error term. Variable α_i represents unobservable determinants, and λ_s is the si-do specific effect.

Recently, many economic studies have pointed out that the ordinary least squares estimates of the above equation are likely to be biased. This is because BW is the output of the household production function where inputs, included in the regression, are endogenously determined by the parents (Rosenzweig and Schultz 1983; Grossman and Joyce 1990). Additionally, numerous factors determine BW, and it is likely that some determinants —such as genetic factors, which correlate with variables in— might be unobservable to econometricians (Abrevaya and Dahl 2008).

To address the endogeneity problem, this study uses grouped-data regressions. Specifically, taking the mean on both sides of the equation by $s \times t$ generates the following equation:

$$\overline{LBW_{st}} = \overline{\alpha_s} + \beta_o \overline{O_{st}} + \beta_x \overline{x_{st}} + \beta_z \overline{z_{st}} + \overline{\epsilon_{st}}$$

where $\overline{\alpha_s} = \frac{1}{N}\sum_{i \in S}\alpha_i + \lambda_s$ is the altered group-specific effect. Consistently estimating $\overline{\alpha_s}$, β_o, β_x, β_z, for each si-do. LBW is predicted in each year as follows:

$$\overline{\widehat{LBW}_{st}} = \widehat{\overline{\alpha_s}} + \hat{\beta}_o \overline{O_{st}} + \hat{\beta}_x \overline{x_{st}} + \hat{\beta}_z \overline{z_{st}}$$

Then, the predicted mean LBW for year t can be calculated as follows:

$$\widehat{LBW_t} = \sum_S \omega_{st} \overline{\widehat{LBW}_{st}} \tag{1}$$

where ω_{st} is the portion of births from group s among total births in year t.

This study also conduct a regression analysis for trend in gestation weeks. The equation at the individual level is as follows:

$$GW_{ist} = \beta'_o O_{ist} + \beta'_x x_{ist} + \beta'_z z_{ist} + \alpha'_i + \lambda'_s + \epsilon'_{ist}$$

where z'_{ist} comprises of birth outcomes such as gender of infants, birth order and season at birth and ϵ'_{ist} is the error term.

Similarly, taking the mean on both sides of the equation by $s \times t$ generates the following equation:

$$\overline{GW_{ist}} = \overline{\alpha}'_s + \beta'_o \overline{O_{st}} + \beta'_x \overline{x_{st}} + \beta'_z \overline{z_{st}} + \overline{\epsilon}'_{st}$$

where $\overline{\alpha'_s} = \frac{1}{N}\sum_{i \in S}\alpha'_i + \lambda'_s$ is the altered group-specific effect. Finally, in the same way as doing above, the predicted mean GW for each si-do in each year and year t can be calculated as follows:

$$\overline{\widehat{GW}_{ist}} = \widehat{\overline{\alpha'_s}} + \hat{\beta'}_o \overline{O_{st}} + \hat{\beta'}_x \overline{x_{st}} + \hat{\beta'}_z \overline{z_{st}}$$

$$\widehat{GW_t} = \sum_S \omega_{st} \overline{\widehat{GW}_{st}} \tag{2}$$

respectively.

To account for the trend of LBW, this study uses birth registration data from Microdata Integrated Service (MDIS) of Statistics Korea and National Health Insurance Service (NHIS) data. This study covers data from 2002 to 2013 and is limited to singleton births in order to explore factors other than plurality (multiple births). The mean birth weight of multiple births is likely to be lower than that of single births. Trying to find out the channels between maternal age or maternal health status and birth outcomes, this study conducts an additional regression. Birth registration data have largely been used to study birth outcome analysis, but there is no information about how to deliver, how maternal health status is. The lack of data makes it difficult to do further research on why the ratio of low birth weight increases. Therefore, this study use NHIS data to obtain more information about methods of delivery and maternal health status.

This study includes LBW, BW and GW as dependent variables, and obstetric interventions(labor induction and Cesarean section), parents' characteristics (maternal age, father's job, maternal education level[2]), birth outcomes(gender of infant, birth order, season at birth) as explanatory variables. And in the complementary analysis, subfertility and gestational diabetes are added in the regression.

Table 1 gives detailed explanation for variables. Our regression is conducted at si-do level, and the data is collapsed by year and si-do, so the variables in the regression indicates mean of the variables at given si-do and year.

2) According to Rosenzweig et al. (1983), mothers (and fathers) with at least a completed high school education seek prenatal care earlier in their pregnancies than do parents with lower schooling attainment. Husband's income also shortens this delay in care; however, a rise in income by 10 percent reduces the delay by less than 1 percent.

Table 1. Description of Variables

Variable	Description	Source
LBW	the ratio of babies < 2,500g	Birth registration data
BW	mean value of birth weight	Birth registration data
GW	mean value of gestation weeks	Birth registration data
Labor induction	the ratio of delivery by inducing labor	NHIS data
Cesarean section	the ratio of delivery by Cesarean section	NHIS data
Maternal age	mean value of mother's age at childbirth	Birth registration data
Father's job	the proportion of white collar workers among fathers	Birth registration data
Maternal eduction level	the ratio of mothers whose education level ≥ uni/college	Birth registration data
Gender of infant	the ratio of boy babies	Birth registration data
Birth order	the ratio of firstborn babies	Birth registration data
Spring	the ratio of babies born in spring	Birth registration data
Summer	the ratio of babies born in summer	Birth registration data
Fall	the ratio of babies born in fall	Birth registration data
Winter	the ratio of babies born in winter	Birth registration data
Subfertility	the ratio of mothers who get treatment for subfertility	NHIS data
Gestational diabetes	the ratio of mothers who have gestational diabetes	NHIS data

Table 2 presents the sample means of key variables in 2002 and 2013 used in the regression analysis and changes between the given two years. Panel A presents the means of birth outcomes. It is notable that the key birth outcomes got worse. The mean BW dropped by 50 grams, the proportion of LBW babies increased by 0.7 percentage points and the average number of gestational weeks decreased from 39.2 to 38.7, or by about 0.5 weeks (3.5 days). Panel B shows the means and changes of the ratio of using obstetric intervention. While the ratio of delivery through C-section decreased slightly from 33.3% to 32.0%, the ratio of delivery by inducing labor nearly doubled from 12.6% to 23.6%. Panel C illustrates the mean maternal age increased by 2.3, and the mother's education level and father's socioeconomic status got higher on average. The last panel shows that maternal health status aggravated.

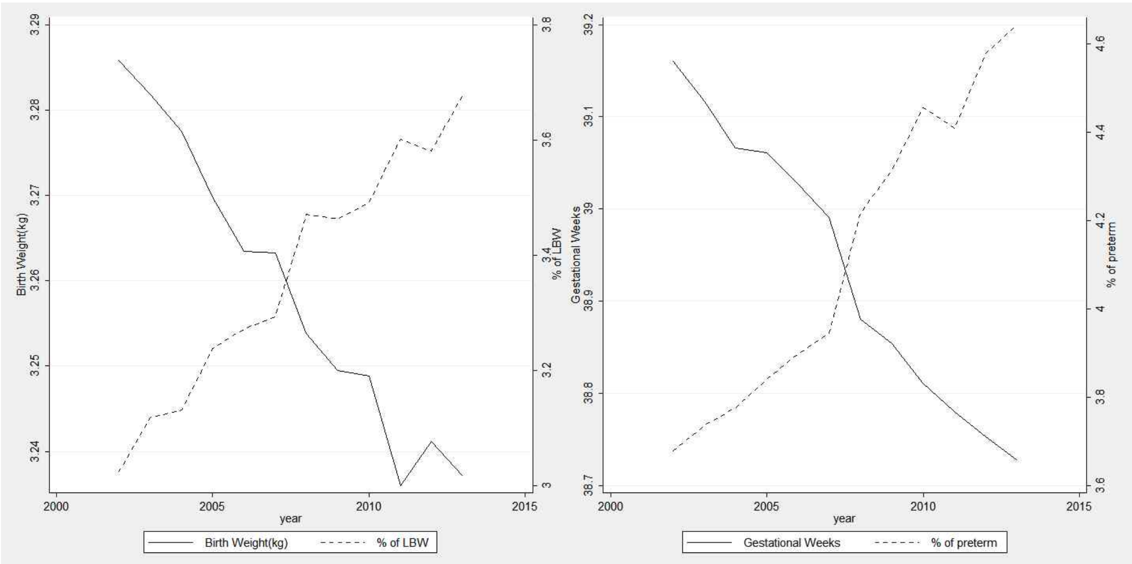
Subfertility tripled and gestational diabetes rose about five times.

Table 2. Summary Statistics: Sample Mean of Key Variables by Year

	2002	2013	change
Panel A : Birth Outcomes			
Birth weight	3.28	3.23	-0.05
LBW(%)	3.0	3.7	0.7
Gender(boy)(%)	52.4	51.3	-1.1
Birth order(firstborn)(%)	49.2	52.1	2.9
Spring(%)	26.8	25.5	-1.3
Summer(%)	23.6	24.2	0.6
Fall(%)	23.6	24.5	0.9
Winter(%)	26.0	25.9	-0.1
Gestational weeks	39.2	38.7	-0.5
Panel B : Obstetric Interventions			
Labor induction(%)	12.6	23.6	11.0
C-section(%)	33.3	32.0	-1.3
Panel C : Parent's Characteristic			
Maternal age	29.0	31.3	2.3
Fathers' job(white-collar)(%)	81.3	82.1	0.8
Maternal education level(≥uni/college)(%)	44.4	73.2	28.8
Panel D :Health Status			
Subfertility	4.0	12.7	8.7
Gestational diabetes	4.5	23.9	19.4

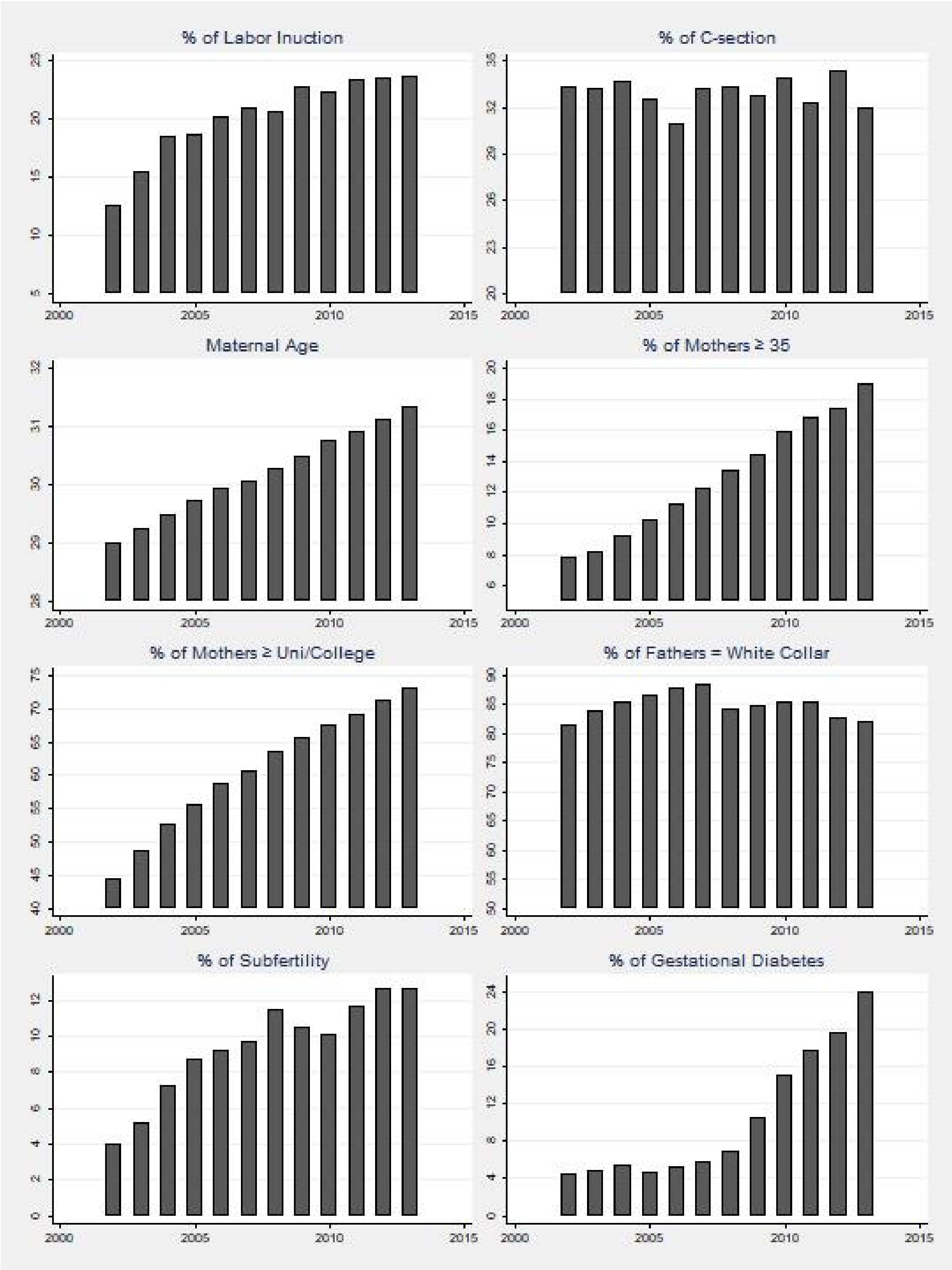
Note : For each variable, the change means difference between 2002 and 2013.

Figure 1. Trends in Birth Outcomes



Note : Preterm means babies who born earlier than 37 weeks.

Figure 2. Trends in Birth Weight Determinants



4. Effect of Maternal Age on Birth Outcomes

Table 3 shows the main estimation results for equation (1). Since this study uses sido-level regressions, each observation is weighted by the number of individual births in the corresponding sido group.

The coefficient in column (1) presents results when only the ratio of obstetric intervention is considered. 1 percentage point increase in the ratio of labor induction use is estimated to increase LBW by 0.0234 percentage points and 1 percentage point increase in the ratio of C-section delivery is estimated to increase LBW by 0.0114 percentage points. In column (2), the ratio of LBW increases by 0.27 percentage points as mother gets one year older. Column (3) represents estimation results when the above-mentioned variables taken together. With these variable included in the analysis, all coefficients decrease compared to column (1) and (2).

Column (4) and (5) additionally include parents' characteristics and birth outcomes of infants. These columns indicate that 1 percentage point increase in the ratio of labor induction increases the ratio of LBW by 0.009 percentage points and the rate of LBW increases by 0.24 percentage points with mother's age. The column also shows that 1 percentage point increase in the proportion of white collar workers among fathers decreases LBW by 0.014 percentage points.

In table 4, the change in the ratio of LBW is decomposed into the parts explained by changes in the explanatory variables, using the estimated coefficients above and the change in explanatory variables in Table 2.

In column (5), It turns out that maternal age is the key factor of increasing LBW. The increase in maternal age predicts about 0.57 percentage points decrease in the ratio of LBW, which account for 87 percent of the change. Also, the increase in the ratio of labor induction predicts about 0.1 percentage points decrease in the ratio of LBW.

Table 3. Effects of Maternal Age on Increasing Low Birth Weight and Significance of Gestational Weeks in Explaining Increasing Low Birth Weight

	LBW					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Obstetric intervention						
Labor induction	0.0234***		0.0129***	0.0086***	0.0091***	0.0045*
	(0.0030)		(0.0028)	(0.0025)	(0.0029)	(0.0024)
C-section	0.0114**		0.0065*	0.0021	0.0024	0.0030
	(0.0044)		(0.0038)	(0.0040)	(0.0042)	(0.0035)
Parent's characteristics						
Maternal age		0.0020***	0.0016***	0.0024***	0.0024***	0.0001
		(0.0002)	(0.0002)	(0.0005)	(0.0005)	(0.0005)
Father's job (white-collar)				-0.0142***	-0.0137***	-0.0004
				(0.0016)	(0.0022)	(0.0023)
Maternal education level (≥uni/college)				-0.0013	-0.0011	-0.0021
				(0.0035)	(0.0038)	(0.0031)
Birth outcomes						
Gender(boy)					0.0118	0.0208
					(0.0353)	(0.0292)
Birth order (firstborn)					-0.0009	0.0126***
					(0.0051)	(0.0045)
Summer					0.0021	-0.0080
					(0.0376)	(0.0312)
Fall					-0.0089	-0.0173
					(0.0255)	(0.0211)
Winter					-0.0132	0.0022
					(0.0384)	(0.0318)
GW						0.0139***
						(0.0015)
Constant	0.0251***	-.0253***	-0.0195***	-0.0294**	-0.0306	0.5580***
	(0.0017)	(0.0052)	(0.0052)	(0.0114)	(0.0387)	(0.0714)
Observations	194	194	194	194	194	194
R-squared	0.240	0.740	0.465	0.621	0.622	0.742

Note : All regressions use the grouped sample. The sample size of each group was used as a regression weight. Robust standard errors are reported in parentheses. A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

Table 4. Decomposition of the LBW Change

	LBW					
	(1)	(3)	(5)		(6)	
Obstetric Intervention						
Labor induction	0.2574***	0.1411***	0.0990***	(16.6)	0.0492*	(8.0)
C-section	-0.0158**	0.0090*	-0.0041	(-0.7)	-0.0042	(-0.7)
Parents' Characteristic						
Maternal age		0.3728***	0.5662***	(95.2)	0.0301	(4.9)
Fathers' job (white-collar)			-0.0108***	(-1.8)	0.0003	(0.0)
Maternal education level (≥uni/college)			-0.0320	(-5.4)	-0.0600	(-9.8)
Birth Outcomes						
Gender(boy)			-0.0129	(-2.2)	-0.0227	(-3.7)
Order(firstborn)			-0.0026	(-0.4)	0.0369***	(6.0)
Summer			0.0013	(0.2)	-0.0047	(-0.8)
Fall			-0.0078	(-1.3)	-0.0151	(-2.5)
Winter			-0.0013	(-0.2)	0.0002	(0.0)
GW					0.6025***	(98.4)

Note : Each column uses the coefficient of the same-numbered column on the table 3. A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%. And figures in parentheses refer to the variable's contribution to total estimated change(%).

Table 5 shows the estimation results for birth weight. The results are similar to those for LBW. The coefficient in column (1) presents results when only the ratio of obstetric intervention is considered. 10 percentage point increase in the ratio of labor induction use is estimated to decrease BW by 18 grams. Column (2) represents estimation results when obstetric interventions and maternal age taken together. The adverse effect of labor induction decrease in comparison with column (1) and BW decreases by 13 grams as maternal age gets one year older. Column (4) additionally includes parents' characteristics and birth outcomes of infants. This columns indicate that 10 percentage point increase in the ratio of labor induction decrease BW by 5 grams and BW decrease by 15 grams with mother's age.

Table 5. Effects of Maternal Age on Dereasing Birth Weight and Significance of Gestational Weeks in Explaining Dereasing Birth Weight

	BW				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Obstetric intervention					
Labor induction	-0.1780***	-0.0906***	-0.0609***	-0.0482***	-0.0160
	(0.0216)	(0.0184)	(0.0155)	(0.0172)	(0.0132)
C-section	-0.0351	0.0057	0.0293	0.0417*	0.0372*
	(0.0315)	(0.0247)	(0.0247)	(0.0252)	(0.0190)
Parent's characteristics					
Maternal age		-0.0134***	-0.0178***	-0.0152***	0.0008
		(0.0012)	(0.0030)	(0.0031)	(0.0027)
Father's job			0.1050***	0.1020***	0.0092
(white-collar)			(0.0099)	(0.0133)	(0.0127)
Maternal			-0.0035	-0.0073	-0.0006
education level (≥uni/college)			(0.0216)	(0.0226)	(0.0170)
Birth Outcomes					
Gender(boy)				0.2370	0.1750
				(0.210)	(0.1580)
Birth order(firstborn)				0.0011	-0.0928***
				(0.0304)	(0.0242)
Summer				-0.420*	-0.3490**
				(0.2240)	(0.1690)
Fall				0.0863	0.1441
				(0.1520)	(0.1143)
Winter				0.2220	0.1150
				(0.2290)	(0.1722)
GW					0.0965***
					(0.0082)
Constant	3.3071***	3.6792***	3.7133***	3.5301***	-0.5630
	(0.0124)	(0.0342)	(0.0704)	(0.230)	(0.3870)
Observations	194	194	194	194	194
R-squared	0.268	0.563	0.727	0.747	0.857

Note : All regressions use the grouped sample. The sample size of each group was used as a regression weight. Robust standard errors are reported in parentheses. A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

The column also shows that the proportion of white collar workers among fathers and the ratio of delivery through C-section is positively correlated to BW. 10 percentage point increase in the ratio of delivery through C-section and the proportion of white collar workers among fathers increase BW by 4 grams and 11 grams, respectively.

It is no wonder that increase in maternal age and labor induction lead to more LBW, because both make babies born earlier than 40 weeks. The prevalence of preterm births, early neonatal mortality, low birth weight, NICU admission, and Apgar score <7 at 5 minutes were increased in women with advanced maternal age (Laopaiboon M. et al. 2014). With the inclusion of gestation weeks in column (6) of table 3, the coefficient of labor induction increase, that of maternal age decrease and become insignificant, and one additional week of gestation is estimated to decrease LBW by 1.39 percentage points. Also, column (6) of table 4 shows that most of change in the ratio of LBW is explained by the change in the gestation weeks. Column (5) in table 5 draws the similar results. With the inclusion of GW, the ratio of labor induction and maternal age get insignificant.

Table 6 represents the estimation results for equation (2) to find out why the gestation weeks shorten. In column (1), it is estimated that 10 percentage points increase in the ratio of labor induction and C-section shorten gestation weeks by 0.15 weeks (1 day) and 0.07 weeks (0.5 days) respectively. With the inclusion of maternal age, the coefficients of them decrease by almost half and one additional year of maternal age shortens gestation weeks by 0.11 weeks (0.8 days). When all variables included, the coefficient of labor induction means that 10 percentage points increase in the ratio of labor induction shorten gestation weeks by 0.03 weeks, and that of maternal age means that one additional year of maternal age shortens gestation weeks by 0.17 weeks. Additionally, column (4) shows that the proportions of white collar workers among fathers and that of firstborn among infants have positive effect on gestation weeks.

This estimation result indicates that the increase in maternal age and increase in the ratio of labor induction predicts about 0.3818 and 0.0366 weeks, respectively, decrease of gestation weeks, which account for 88 and 8.5 percent of GW change amount. Increase in the proportion of white collar workers among fathers and firstborn have positive impact on GW, but the impact size is small(< 0.02 weeks). Then, it can be said that maternal age is a key factor for determining gestation weeks.

Table 6. Effect of Maternal Age on Gestational Weeks

	GW			
VARIABLES	(1)	(2)	(3)	(4)
Obstetric intervention				
Labor Induction	-1.5063***	-0.7860***	-0.4363***	-0.3330***
	(0.1867)	(0.1647)	(0.1094)	(0.117)
C-section	-0.6572**	-0.3224	-0.0151	0.0469
	(0.2731)	(0.2209)	(0.1745)	(0.1731)
Parent's characteristics				
Maternal age		-0.1098***	-0.1678***	-0.1661***
		(0.0106)	(0.0211)	(0.0212)
Fathers' job			1.2037***	0.9590***
(white-collar)			(0.0703)	(0.0908)
Maternal education level			0.0159	-0.0692
(≥uni/college)			(0.1526)	(0.1540)
Birth Outcomes				
Gender(boy)				0.6461
				(1.4360)
Birth order(firstborn)				0.9730***
				(0.2080)
Summer				-0.7320
				(1.5310)
Fall				-0.6030
				(1.0360)
Winter				1.1140
				(1.5630)
Constant	39.4584***	42.5179***	43.0660***	42.4270***
	(0.1070)	(0.3063)	(0.4978)	(1.5731)
Observations	194	194	194	194
R-squared	0.2544	0.5250	0.8149	0.839

Note : All regressions use the grouped sample. The sample size of each group was used as a regression weight. Robust standard errors are reported in parentheses. A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

From the above results, it can be said that increased maternal age is a leading factor in increasing LBW and decreasing BW by negatively affecting the gestational weeks.

5. Why did Gestational Weeks Decrease with Maternal Age?

The main result of this paper is that increase of maternal age is a significant factor for changes in birth outcomes from 2002 to 2013. This result leads to a question : why did gestation weeks shorten with maternal age?

There are many possible channels through which maternal age can affect gestation weeks. Plausible explanation is that pregnant women's health status or medical risk profiles get worse with age. A lot of studies have showed that risk of sub-fertility, gestational complications, adverse birth outcomes increase with age.

There have been a number of studies that the increasing of maternal age adversely affects birth outcomes. Pregnant women who are more than 35 years old have greater odds for preterm delivery, hypertension, superimposed preeclampsia, severe preeclampsia, and decreased risk for chorioamnionitis. Older women (≥40 years old) have increased odds for mild preeclampsia, fetal distress, and poor fetal growth (Cavazos-Rehg et al. 2015).

The risks for pregnancy complications and adverse outcomes increase with advancing age, except for premature rupture of membranes; the highest risks for women ≥45 years compared with ages 30–34 are for chronic hypertension [adjusted odds ratio (AOR) 3.70], diabetes (AOR 2.19), birth <32 weeks (AOR 2.11) and pregnancy-associated hypertension (AOR 1.55) (Luke et al. 2007).

Advanced maternal age at birth is considered a major risk factor for birth outcomes. When compared with maternal ages 25–29 years, maternal ages of 35–39 years and ≥40 years are associated with percentage increases of 1.1 points (95% confidence intervals: 0.8, 1.4) and 2.2 points (95% confidence intervals: 1.4, 2.9), respectively, in the probability of low birth weight. The associations are similar for the risk of preterm delivery (Goisis et al. 2017).

Table 7 shows the relation between maternal health status and maternal age, chronic disease, lifestyle. From column (3) in the table, risk of subfertility increases by 1.4 percentage points as mother gets one year older and by 1.1 percentage points if mother is obese. Also, hyperlipidemia, smoking and drinking have negative impact on the risk of subfertility. Figures in column (6) shows that the risk of gestational diabetes increases by 0.7 percentage points as mother gets one year older and by 3.2 percentage points if mother is obese. Hypertension and hyperlipidemia also have negative effects on the risk. Then, it can be said that risk of maternal health status increase with maternal age.

Table 7. Effect of Maternal Age on Increasing Risk of Health Status

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		Subfertility			Gestational diabetes	
Maternal age	0.0093***	0.0144***	0.0139***	0.0075***	0.0073***	0.0073***
	(0.0047)	(0.0152)	(0.0149)	(0.0882)	(0.0895)	(0.0897)
Obesity		0.0104***	0.0109***	0.0367***	0.0323***	0.0317***
		(0.0208)	(0.0204)	(0.0930)	(0.0951)	(0.0951)
Hypertension		0.0065	0.0034		0.0514**	0.0517**
		(0.0571)	(0.0558)		(0.0262)	(0.0262)
Diabetes		-0.0520	-0.0516		0.0276	0.0281
		(0.0697)	(0.0682)		(0.0356)	(0.0356)
Hyperlipidemia		0.0994***	0.0981***		0.0369***	0.0374***
		(0.0185)	(0.0182)		(0.0096)	(0.0096)
Smoking			0.306***			0.0533
			(0.0628)			(0.0458)
Drinking			0.159***			0.0164
			(0.0504)			(0.0381)
Constant	-0.127***	0.0389	-0.0302	-0.124***	-0.132***	-0.133***
	(0.0150)	(0.0643)	(0.0638)	(0.0277)	(0.0278)	(0.0278)
Observations	8,438	8,438	8,438	8,438	8,438	8,438
R-squared	0.113	0.350	0.761	0.118	0.414	0.537

Note : All regressions use the individual sample. A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

A. Subfertility

Births to subfertile women, with and without infertility treatment, have been reported to have lower birth weights and shorter gestation weeks, even when limited to singletons. And with subfertile women as reference, risks for the in vitro fertilization group are significantly increased for uterine bleeding, placental complications, prenatal hospitalizations, primary cesarean delivery, low and very low birthweight, and preterm and very preterm birth (Luke et al. 2017).

As maternal age grows, the proportion of subfertile women increases and affects the gestation weeks directly or indirectly. Directly gestation weeks decrease by 0.1 weeks as the proportion of subfertile women increase 10 percentage points. Indirectly it can affect gestation weeks through labor induction, which means the possibility of labor induction increase by 0.377 percentage points as the proportion of subfertile women increases by 1 percentage point. Between 2002 and 2013, the proportion of subfertile women increased by 8.7 percentage points. Then, it can be calculated that the proportion of subfertile women indirectly decrease GW by about 0.05 weeks.

Table 8. Effects of Subfertility on the Ratio of Labor Induction and Gestational Weeks

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Labor induction	Labor Induction	GW	GW	GW
Subfertility	0.499***	0.377***	-1.287***	-1.345***	-0.963***
	(0.119)	(0.130)	(0.331)	(0.315)	(0.297)
Father's job (white-collar)		-0.0779		1.492***	1.633***
		(0.0770)		(0.187)	(0.176)
Maternal education level(≥high)		-0.139		-10.07***	-12.18***
		(0.675)		(1.701)	(1.541)
Gender(boy)		-5.585***			14.76***
		(0.808)			(1.845)
Birth order(firstborn)		-0.216			1.044***
		(0.164)			(0.374)
Constant	0.160***	3.372***	39.05***	47.63***	41.37***
	(0.00999)	(0.720)	(0.0278)	(1.544)	(1.644)
Observations	177	177	177	177	177
R-squared	0.092	0.301	0.080	0.326	0.524

Note : A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

B. Gestational Diabetes

Older women have a higher risk of experiencing pregnancy complications which raise the likelihood of early delivery. It has been suggested that older age is related to these adverse outcomes through biomedical mechanisms, because at older ages, in addition to ageing oocytes, women are more likely to have pre-existing diseases, reduced cardiovascular reserve and, as a consequence, greater difficulty with sustaining the pregnancy after successful implantation (Laolor et al. 2011).

Similarly, the proportion of gestational diabetes among pregnant women increases with age and it can affects the gestation weeks directly or indirectly. Directly, gestation weeks decrease by 0.12 weeks he proportion of gestational diabetes among pregnant women increase 10 percentage points. Indirectly the proportion of gestational diabetes among pregnant women increase labor induction by 0.271 percentage points. From 2002 to 2013, the proportion of gestational diabetes among pregnant women increased by 19.5 percentage points. Then, it can be calculated that the proportion of subfertile women directly decrease GW by 0.21 weeks and indirectly by about 0.044 weeks.

Table 9. Effects of Gestational Diabetes on the Ratio of Labor Induction and Gestational Weeks

VARIABLES	(1) labor induction	(2) labor induction	(3) GW	(4) GW
Gestational diabetes	0.271***	0.147**	-1.658***	-1.217***
	(0.0519)	(0.0612)	(0.106)	(0.110)
Father's job(white-collar)		-0.0277		1.113***
		(0.0761)		(0.137)
Maternal education level (≥high)		-0.682		-6.518***
		(0.721)		(1.298)
Gender(boy)		-5.294***		8.859***
		(0.832)		(1.499)
Birth order(firstborn)		-0.0600		0.557**
		(0.150)		(0.270)
Constant	0.174***	3.644***	39.11***	39.62***
	(0.00654)	(0.716)	(0.0133)	(1.290)
Observations	194	194	194	194
R-squared	0.124	0.293	0.561	0.723

Note : A single asterisk denotes statistical significance at the 90% confidence level; double, 95%; and triple, 99%.

6. Summary and Concluding Remarks

As the rate for low birth weight babies has increased to alarming level in Korea, there is growing concern about its potential impact on individuals and society. While its short-term impact is debatable, numerous studies have found that the long-term impact on cognitive development or health status at adult is still significant. Examining the birth registration data from 2002 to 2013, this study finds that the rise in maternal age are strongly related to the trend of increasing ratio of LBW, as well as decreasing BW. Taking a closer look, gestation weeks play an important channel behind the relation between maternal age and birth outcomes. Gestation weeks shorten with age and then the birth outcomes get worse.

Then this paper tries to find the reason maternal age have a negative impact of gestation weeks. As mother gets older, the risk of subfertility and gestational diabetes increases. This health problems pre/during-pregnancy directly makes babies born earlier than 40 weeks and also indirectly affects gestational weeks by making the possibility of using labor induction increase.

It is possible that other factors not addressed in this study have also contributed recent trend. However, it is important to be aware of that increasing LBW can be a burden on society as well on each individual. The economic costs in the short-term are hospital costs related to intensive care and decrease in wage in the long-term. Nearly all low birth weight babies need specialized care in the Neonatal Intensive Care Unit (NICU), and in 2016 the average hospital cost of babies weighing 1000-1500 grams at birth exceeded 28 million won and weighing 2000-2500 grams amounts to about 10 million won and government's expenditure on policy of fundholding for LBW exceeded 11.3 billion won. Taking the recent trend of rise in the number of multiple birth and increasing maternal age into accont, the costs on society are likely to keep increasing. Thus, increasing incidence of subfertility and gestational diabetes, or poor maternal health status, deserves attention since this health risk can aggravate birth outcomes, and result in being a burden for individual and society alike. Therefore, any policies and campaigns that tackles pre/during-pregnancy maternal health status, such as recommendation on medical examination prior to pregnancy or participating moms′ classes, should be carefully designed by taking into account these potential benefits and costs.

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국문초록

산모가 고령일수록 저체중아 출산 위험이 커지는가
: 한국에 대한 경제학 연구

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1990년 이후로 저체중아 비율은 꾸준히 증가하여 현재 우려할 만한 수준에 이르렀다. 보건전문가 및 관련 정책 담당자는 저체중아 비율의 증가가 장단기적으로 사회에 큰 부담이 될 수 있다는 점에서 이러한 추세에 우려를 표하고 있다. 그러나 대부분의 출생 체중 결정 요인들이 긍정적인 방향으로 변하고 있는 상황에서 이러한 추세는 예상치 못한 것이다. 출생 신고 자료를 이용하여 분석한 결과, 본 연구는 산모 연령의 증가가 저체중아 비율 및 출생 체중에 가장 큰 부정적인 영향을 미쳤다는 것을 보여준다. 구체적으로, 산모의 고령화는 임신 주수의 감소를 가져왔으며, 이는 저체중아의 증가와 같은 부정적인 출산 결과를 가져왔다. 이와 더불어, 본 연구는 산모의 나이가 임신 주수에 부정적인 영향을 미치는 이유를 파악하고자 하였다. 분석 결과는 산모의 연령 증가에 따른 난임 및 임신성 당뇨의 증가가 임신 주수를 감소시켰을 것이라는 것을 보여준다. 2016년 기준 저제중아의 평균 입원비가 1500만원이고, 2007년 저체중아 의료비 지원 정부 지원액이 120억원이 넘는다는 점에서 저체중아의 증가는 개인, 사회 모두에게 부담이 될 수 있다. 따라서 출생 결과 증진을 위해서 임신 이전, 이후의 출산건강 관리 방안 및 관련 캠페인이 마련될 필요가 있다.

주요어 : 저체중아, 산모 연령, 임신 주수, 유도분만, 난임, 임신성 당뇨
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