

THE IMPACT OF MATERNAL SMOKING HABITS DURING PREGNANCY ON BIRTH WEIGHT

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Abstract

Birth weight is an important indicator in assessing the health of both the baby and the mother during pregnancy. One behavioral factor suspected of influencing adverse birth outcomes is maternal smoking during pregnancy. This study aims to modify the impact of maternal smoking on birth weight using an Impact Evaluation approach using the Propensity Score Matching (PSM) method. The data used consisted of 4,642 observations of mothers and babies, with birth weight as the primary outcome variable and maternal smoking status during pregnancy as the treatment variable. The analysis showed that before the matching process, there was a difference in average birth weight of 275 grams between babies born to mothers who smoked and those who did not smoke. After adjusting for maternal characteristics using the PSM method, this difference remained significant, with an Average Treatment Effect on the Treated (ATT) value of approximately -197 grams. Other estimates using the ATET and nearest neighbor approaches also showed that babies born to mothers who smoked had birth weights approximately 200–226 grams lower than babies born to mothers who did not smoke. These findings indicate that smoking during pregnancy has a significant negative impact on birth weight, even after controlling for various maternal social and demographic characteristics. Therefore, efforts to control smoking behavior in pregnant women are crucial as part of public health policies to improve infant health from birth.

Keywords: Propensity Score Matching, Impact Evaluation, Birth Weight, Smoking During Pregnancy, Maternal and Child Health

INTRODUCTION

Background

Maternal and infant health is a crucial issue in health development in various countries, including Indonesia. One indicator often used to assess the health of newborns is birth weight. Low birth weight can increase the risk of health problems, developmental delays, and even increase infant mortality rates. Therefore, various factors that can influence birth weight require serious attention.

One behavioral factor that has the potential to affect infant health is smoking during pregnancy. Smoking can reduce the supply of oxygen and nutrients received by the fetus through the placenta. Harmful substances such as nicotine and carbon monoxide in cigarettes can inhibit fetal growth, thereby increasing the risk of low birth weight. Several previous studies have shown that babies born to mothers who smoke tend to have lower birth weights than babies born to non-smoking mothers.

However, the relationship between maternal smoking and birth weight cannot always be interpreted directly as a cause-and-effect relationship. This is because various other factors also influence birth weight, such as maternal age, education level, marital status, and access to healthcare during pregnancy.

Therefore, an analytical method is needed that can reduce bias due to differences in characteristics between groups of mothers who smoke and those who do not smoke.

One approach that can be used is Impact Evaluation using the Propensity Score Matching (PSM) method. This method allows researchers to match individuals with similar characteristics between the treatment and control groups, thus resulting in a closer estimate of the impact of the relationship. With this approach, the effect of smoking during pregnancy on birth weight can be analyzed more accurately.

Problem Formulation

Based on this background, the research questions that can be formulated in this study are:

1. Is there a difference in birth weight between mothers who smoke during pregnancy and mothers who do not smoke?
2. How significant is the impact of smoking during pregnancy on birth weight after controlling for maternal social and demographic characteristics?

Research Purposes

This study aims to:

1. Analyze differences in birth weight between mothers who smoke and those who do not smoke during pregnancy.
2. Estimate the impact of maternal smoking during pregnancy on birth weight using the Propensity Score Matching method as an impact evaluation approach.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Birth Weight as a Health Indicator

Birth weight is an important indicator in assessing infant health conditions as well as the quality of pregnancy. Infants with low birth weight (LBW), defined as less than 2,500 grams, have a higher risk of health problems such as growth retardation, developmental disorders, and increased neonatal mortality. Therefore, birth weight is commonly used as a key indicator in public health and health economics studies.

Birth weight is influenced by various factors, including both biological and non-biological determinants. Biological factors include maternal health conditions, gestational age, and nutritional status during pregnancy. Meanwhile, non-biological factors include socioeconomic conditions, education level, access to healthcare services, and maternal behaviors during pregnancy, including smoking, which is one of the major risk factors.

Furthermore, birth weight reflects the quality of the prenatal environment experienced by the fetus during pregnancy. A favorable prenatal environment supports optimal fetal growth, whereas unfavorable conditions may hinder development. Thus, birth weight is not only an indicator of short-term health but also has long-term implications for individual health and productivity.

The Impact of Smoking During Pregnancy

Smoking during pregnancy is a behavior that negatively affects fetal development. Harmful substances in cigarettes, such as nicotine and carbon monoxide, reduce oxygen supply to the fetus, thereby inhibiting intrauterine growth. This condition limits the fetus's ability to obtain optimal nutrients, ultimately affecting birth weight.

Empirical evidence shows a significant difference in birth weight between infants born to smoking and non-smoking mothers. The average birth weight of infants born to non-smoking mothers is 3,412.91 grams, whereas those born to smoking mothers is 3,137.66 grams, indicating a difference of approximately 275 grams. This suggests that smoking during pregnancy has a negative effect on birth weight.

The impact of smoking is not limited to lower birth weight but also increases the risk of pregnancy complications such as preterm birth and impaired fetal organ development. Exposure to toxic substances can disrupt placental function, reducing the efficiency of oxygen and nutrient transfer. Additionally, the intensity and duration of smoking may exacerbate these effects. The more frequently a mother smokes during pregnancy, the higher the risk of fetal growth restriction. Therefore, smoking during pregnancy can be categorized as a significant risk factor that requires attention in efforts to improve maternal and child health.

Social and Demographic Factors in Smoking Behavior

Smoking behavior among pregnant women is influenced by various social and demographic factors, such as education level, marital status, age, and access to healthcare services. A study by Cutler and Lleras-Muney (2017) shows that education significantly affects health behavior, where individuals with lower education levels are more likely to smoke.

In addition, demographic factors such as marital status and socioeconomic conditions also contribute to mothers' decisions to smoke during pregnancy. Differences in individual characteristics may lead to selection bias in analysis, as smoking and non-smoking mothers are not fully comparable. Therefore, a method that can control for these differences is needed to produce more accurate estimates. In this study, the Propensity Score Matching (PSM) approach is used to address this issue.

Concept of Causal Inference

In empirical research, it is important to distinguish between correlation and causality. Correlation indicates an association between variables, whereas causality refers to a direct effect of one variable on another. The causal inference approach is used to identify the impact of a treatment on an outcome while controlling for potential biases in observational data.

According to Cunningham (2021), this approach allows for more accurate estimation of causal relationships even in the absence of experimental data. In this study, smoking during pregnancy is treated as the treatment variable, while birth weight is considered the outcome variable, in order to identify the causal effect.

Propensity Score Matching (PSM)

Propensity Score Matching (PSM) is a method used to reduce selection bias in observational studies by comparing treatment and control groups with similar characteristics. The propensity score is defined as the probability of an individual receiving treatment based on observed covariates.

Through this approach, individuals in the treatment group are matched with individuals in the control group who have similar propensity scores, so that the observed differences in outcomes more accurately reflect the causal effect of the treatment. PSM is widely used within the causal inference framework to obtain less biased estimates when experimental data are not available.

In this study, PSM is used to match smoking mothers with non-smoking mothers based on social and demographic characteristics, ensuring a more valid comparison of birth weight outcomes.

Average Treatment Effect on the Treated (ATT/ATET)

The Average Treatment Effect on the Treated (ATT) measures the average impact of a treatment on individuals who actually receive the treatment. In this study, ATT is used to estimate the effect of smoking during pregnancy on birth weight among smoking mothers.

The analysis shows that after matching, infants born to smoking mothers have an average birth weight approximately 197 grams lower than those born to non-smoking mothers with similar characteristics. This result remains statistically significant, indicating a real effect of smoking on birth weight.

The reduction in the difference before and after matching suggests that part of the initial difference was influenced by maternal characteristics such as social and demographic factors. However, the remaining difference after matching indicates a direct effect of smoking on birth weight. Therefore, ATT provides a more accurate estimate of the impact of smoking, as it accounts for similarities between groups. These findings reinforce that smoking during pregnancy consistently contributes to lower birth weight.

Previous Studies

Previous studies consistently show that smoking during pregnancy has a negative impact on birth weight. Abrevaya (2019) finds that smoking mothers tend to give birth to lower-weight infants, even after controlling for socioeconomic factors. Similarly, Bharadwaj et al. (2021) demonstrate that using a causal inference approach, the effect remains significant after addressing selection bias.

Moreover, social and demographic factors such as education and economic conditions also influence smoking behavior among pregnant women. Cutler and Lleras-Muney (2017) state that individuals with lower levels of education are more likely to engage in unhealthy behaviors, including smoking.

Based on theoretical and empirical evidence, it can be concluded that smoking during pregnancy reduces birth weight and is influenced by social and demographic factors. Therefore, methods such as Propensity Score Matching (PSM) are needed to control for individual differences and obtain more accurate estimates.

Based on the theoretical framework and previous studies, the hypotheses of this study are formulated as follows:

H0: Smoking during pregnancy has no effect on birth weight.

H1: Smoking during pregnancy has a negative and significant effect on birth weight.

H2: The negative effect of smoking during pregnancy on birth weight remains significant after controlling for maternal characteristics using Propensity Score Matching (PSM).

Conceptual Framework

This study is motivated by the issue of differences in characteristics between smoking and non-smoking mothers, which may lead to bias in analysis. To address this issue, Propensity Score Matching (PSM) is used to balance the characteristics of both groups before comparison.

Through this approach, the observed differences in birth weight more accurately reflect the direct effect of smoking behavior. Conceptually, smoking during pregnancy affects fetal growth, which in turn impacts birth weight. However, this relationship is controlled for social and demographic variables to ensure more accurate and unbiased results.

RESEARCH METHODS

Research Design

This study adopts a quantitative approach using an impact evaluation framework to examine the causal effect of maternal smoking during pregnancy on infant birth weight. The Propensity Score Matching (PSM) method is employed to reduce selection bias arising from

observable differences between the treatment and control groups. This approach allows for a more reliable estimation of causal effects by constructing a comparable control group.

Population and Sample

This study utilizes secondary data obtained from the Datasets for Stata Causal Inference and Treatment-Effects Estimation. The dataset is cross-sectional and consists of 4,642 observations, representing maternal characteristics and infant conditions at birth. The unit of analysis in this study is individual mothers and their corresponding birth outcomes.

Data Collection and Instruments

The data used in this study are secondary data collected from an existing dataset. The variables included in the analysis consist of the outcome variable, treatment variable, and several covariates.

The outcome variable is birth weight (bweight), while the treatment variable is maternal smoking status during pregnancy (mb smoke). In addition, several covariates are included as control variables, namely maternal marital status (mmarried), maternal age (mage), paternal age (fage), maternal education level (medu), and the frequency of prenatal visits (prenatal). These variables are used to represent socio-demographic characteristics that may influence both maternal smoking behavior and infant birth weight, thereby helping to minimize potential bias in the estimation results.

Data Analysis Techniques

The analysis in this study is conducted in several stages. First, a two-sample t-test is performed to identify the initial differences in birth weight between smoking and non-smoking mothers. This test provides a preliminary comparison between groups prior to controlling for covariates and cannot be interpreted as causal.

Second, propensity scores are estimated using a logistic regression model, where the dependent variable is maternal smoking status (mb smoke) and the independent variables include mmarried, mage, fage, medu, and prenatal. This estimation generates the probability of each individual being assigned to the treatment group based on observed characteristics.

Third, a matching process is conducted using the nearest neighbor matching method. Each treated individual is matched with one or more control individuals with the closest propensity score. In this study, multiple nearest neighbors are used to improve the stability of the estimation results and to construct a more comparable control group.

Fourth, the treatment effect is estimated using several measures, including the Average Treatment Effect on the Treated (ATT), the Average Treatment Effect on the Treated (ATET) using a treatment-effects framework, and the Average Treatment Effect (ATE) using nearest neighbor matching. The use of multiple estimators aims to ensure the robustness and consistency of the results.

Fifth, a common support test is conducted to ensure sufficient overlap in the distribution of propensity scores between the treatment and control groups. This step is essential to validate the matching process and support causal interpretation.

Finally, as a complementary analysis, a linear regression model is estimated using the Ordinary Least Squares (OLS) method. This analysis is used as a benchmark to compare the conventional estimation approach with the PSM method in assessing the impact of maternal smoking on birth weight.

RESULTS AND DISCUSSION

Results of The Average Difference Test

Table 1. Results of the Average Difference Test

Variable	Non Smoker	Smoker
Mean	3412.91	3137.66
T Statistic	12.8306	
P - Value	<0.001	
LR χ^2	320.33	
Pseudo R ²	0.0718	
Significant Variables	Marital Status (-0.987), Education (-0.136)	
Non-Significant Variables	Maternal Age (0.052), Paternal Age (0.297), Prenatal Visits (0.065)	

Source: Stata

Based on the results of the logistic regression analysis, the model was significantly effective in explaining variation in maternal smoking behavior (mbsmoke). This is indicated by the Likelihood Ratio chi-square (LR χ^2) value of 320.33 with a p-value <0.001, demonstrating that the independent variables collectively influence the probability of maternal smoking. The Pseudo R² value of 0.0718 suggests that the model accounts for approximately 7.18% of the variation in maternal smoking incidence, which is considered moderate within the context of behavioral research.

Individually, the variable marital status (married) significantly influenced maternal smoking behavior (p <0.001). The negative coefficient (-0.987) signifies that married mothers are less likely to smoke compared to unmarried mothers.

The variable maternal education (medium) also had a significant effect (p <0.001) with a negative coefficient (-0.136), indicating that higher maternal education levels are associated with a lower likelihood of smoking. This highlights the important role of education in shaping health behaviors.

In contrast, the maternal age variable (mage) showed a near-significant effect (p = 0.052) with a positive coefficient, suggesting that as maternal age increases, the likelihood of smoking also tends to increase, although this finding does not reach statistical significance at the 5% confidence level.

The paternal age variable (fage) did not demonstrate a significant effect (p = 0.297), indicating that paternal age is not statistically associated with maternal smoking behavior in this model.

Similarly, the prenatal visits variable (prenatal) was not significant at the 5% level (p = 0.065), despite its positive coefficient. This suggests that the relationship between prenatal visits and maternal smoking behavior is not strong enough to be deemed statistically significant.

In summary, marital status and maternal education level were significant protective factors against maternal smoking behavior. Maternal age and prenatal visits showed a tendency toward an effect but were not statistically significant, while paternal age had no significant effect. The model is considered robust; however, other unmeasured factors may also contribute to maternal smoking behavior.

Propensity Score Results

Table 2. Results of Propensity Score Estimation

Results of Propensity Score Estimation	
Marital Status (<i>mmarried</i>)	-0.9874568
Maternal Education (<i>medu</i>)	0.1364742
Prenatal Visits (<i>prenatal</i>)	0.1293983
_cons	0.3581589
Prob > chi2	0.0000
Paternal Age (<i>fage</i>)	0.0048265

Source: Stata

The propensity score in this study was estimated using a logistic regression model with maternal smoking status (*mbsmoke*) as the dependent variable and covariates including marital status (*mmarried*), maternal age (*mage*), paternal age (*fage*), maternal education (*medu*), and prenatal visits (*prenatal*).

The estimation results showed that the overall model was significant, as indicated by a χ^2 LR value of 320.33 ($p < 0.001$). This indicates that the covariates used together were able to predict the probability of maternal smoking. A pseudo- R^2 value of 0.0718 indicates that the model has sufficient explanatory power in the context of generating the propensity score.

Partially, marital status (*mmarried*) and maternal education (*medu*) significantly influenced the probability of being in the treatment group (mothers who smoke), each with a negative coefficient and a p -value < 0.001 . This indicates that married mothers with higher levels of education tend to have a lower probability of smoking.

The maternal age variable (*mage*) showed a near-significant effect ($p = 0.052$) with a positive direction, indicating a tendency for the probability of smoking to increase with increasing maternal age. Meanwhile, the prenatal visit variable (*prenatal*) also showed a positive trend, although it was not significant at the 5% level ($p = 0.065$).

On the other hand, paternal age (*fage*) did not have a significant effect ($p = 0.297$), so its contribution to differentiating the treatment and control groups was relatively weak.

The logistic regression model used to estimate the propensity score was deemed feasible and statistically significant. The variables that played the most significant role in determining the probability of maternal smoking were marital status and maternal education, while other variables made more limited contributions. Therefore, the resulting propensity score can be used for further processes such as matching, weighting, or stratification, to reduce selection bias in causal analysis.

PSMATCH2 ResultsTable 3. Results of Average Treatment Effects on The Treated (*psmatch2*)

Results of Average Treatment Effects on The Treated	
Treatment Effect (ATT)	-197.5972
Standard Error	33.86976
t-stat	-5.83
Treated (On Support)	864
Treated (On Support)	3,778
Total Observations	4,642

Source: Stata

Based on the estimation results using the Propensity Score Matching (PSM) method with *psmatch2*, all observations fell within the common support area, yielding a total of 4,642 samples,

with 864 in the treatment group (smoking mothers) and 3,778 in the control group (non-smoking mothers). This ensures that matching can be performed optimally without losing observational data.

The treatment effect was estimated using the Average Treatment Effect on the Treated (ATT) for the outcome variable of infant birth weight (bweight). Before matching, the average birth weight for infants born to smoking mothers was 3,137.66 grams, whereas those born to non-smoking mothers averaged 3,412.91 grams—a statistically significant difference of -275.25 grams ($t = -12.83$). This suggests a substantial initial disparity between the two groups.

After matching, the adjusted average birth weight among the control group was 3,335.26 grams. The resulting ATT of -197.60 grams ($t = -5.83$) remained statistically significant. This finding indicates that, even after accounting for comparable characteristics between the treatment and control groups, maternal smoking is associated with a lower average infant birth weight.

In summary, the psmatch2 results show that maternal smoking exerts a negative and significant effect on infant birth weight. Although the difference between the groups decreased after matching (from -275.25 to -197.60 grams), the effect remained statistically robust, suggesting that selection bias was partially addressed but the adverse impact of maternal smoking persisted.

Results of Average Treatment Effects on The Treated (ATET)

Table 4. Results of Average Treatment Effects on The Treated

Results of Average Treatment Effects on The Treated	
Treatment Effect (ATET)	-208.3702
Standard Error	30.62191
z	-6.80
p-value	0.000
95% Confidence Interval (Upper)	-268.3881
95% Confidence Interval (Lower)	-148.3524

Source: Stata

Estimates using the Average Treatment Effect on the Treated (ATET) approach show that the smoking during pregnancy variable has a coefficient of -208.37 grams and is statistically significant at the 1% level (p -value = 0.000). The z -statistic of -6.80 and the 95% confidence interval ranging from -268.39 to -148.35 indicate that the estimate is stable and significantly different from zero.

The ATET approach is used to measure the impact of treatment specifically on the group that actually receives the treatment, namely mothers who smoke during pregnancy.

Therefore, this estimate does not represent the average for the entire population, but rather specifically describes the changes experienced by the group of mothers who smoke.

These results indicate that in the group of mothers who smoke, the average birth weight of babies is approximately 208 grams lower compared to the counterfactual condition, if the mothers had not smoked.

Nearest Neighbor Results

Table 5. Nearest Neighbor Results

Nearest Neighbor Results	
Treatment Effect (ATE)	-226.755
Standard Error	26.31364
z	-8.62
p-value	0.000
95% Confidence Interval (Upper)	-278.3288

95% Confidence Interval (Lower) -175.1812

Source: Stata

Estimation using the nearest neighbor approach with three nearest neighbors ($nn = 3$) yielded an Average Treatment Effect (ATE) value of -226.76 grams, statistically significant at the 1% level (p -value = 0.000). The z -statistic of -8.62 and the 95% confidence interval ranging from -278.33 to -175.18 indicate that the estimation results are robust and consistent.

This approach measures the average treatment effect across the entire population, including both smokers and nonsmokers. These results indicate that, in general, smoking during pregnancy is associated with a reduction in birth weight of approximately 226 grams. Both estimation approaches yielded consistent findings: smoking during pregnancy has a negative and significant effect on birth weight. The magnitude of the effect, which is in the range of 200–226 grams, indicates a substantial impact, considering that birth weight is an important indicator of infant health. The differences between the ATET and ATE results are relatively small, indicating that the estimates are quite stable across the various matching methods used. ATET, which focuses on the group of mothers who smoke, provides a more specific impact estimate, while ATE, using the nearest neighbor approach, provides a broader picture of the average effect across the population.

Regression Results

Table 6. Regression Results

Variable	Regression Results	
	Coefficient	Std. Error
mbsmoke	-220.3985	22.04462
mmarried	164.5151	21.71713
mage	2.362193	1.917097
fage	-.0492281	1.114838
medu	6.823623	3.738985
prenatal	26.36009	16.94264
_cons	3108.055	59.90458

Source: Stata

Observations: 4.642

R-squared: 0.0558

Adj. R-squared: 0.0546

The regression estimation results indicate that the overall model is significant, as evidenced by a Prob > F value of 0.000. Therefore, it can be concluded that the independent variables used in the model simultaneously influence birth weight. However, the R-squared value of 0.0558 indicates that the model explains approximately 5.58% of the variation in birth weight, suggesting that other factors outside the model may influence this variable.

Partially, the "smoking" variable, as the main variable, shows a coefficient of -220.40 grams and is statistically significant at the 1% level (p -value = 0.000). This result indicates that babies born to mothers who smoke have an average weight of approximately 220 grams lower than babies born to mothers who do not smoke, assuming other variables remain constant.

The "married" variable also shows a positive and significant effect, with a coefficient of 164.52 grams (p -value = 0.000). This indicates that babies born to married mothers tend to have higher birth weights than those born to unmarried mothers.

Meanwhile, the variables mage (maternal age) and fage (paternal age) did not show a significant effect on birth weight, as indicated by p -values of 0.218 and 0.965, respectively. This indicates that in this model, parental age does not significantly explain variation in birth weight.

The variable medu (maternal education) showed a positive effect with a coefficient of 6.82 grams, but it was only significant at a lower significance level (p -value = 0.068), making its effect relatively weak. Similarly, the prenatal variables did not show a statistically significant effect (p -value = 0.120), despite having a positive association with birth weight.

CONCLUSION

This study shows that smoking during pregnancy has a negative and significant effect on birth weight. The results of the difference-in-means test showed an initial difference of approximately 275 grams between babies of smoking and non-smoking mothers. After controlling for characteristics using the Propensity Score Matching (PSM) method, this difference decreased but remained significant, with an ATT value of approximately -197 grams. This finding is supported by other estimates, such as ATET (-208 grams) and ATE (-226 grams), which consistently show a negative impact of smoking on birth weight.

These findings indicate that although differences in birth weight are partially influenced by maternal social and demographic factors, smoking still has a direct effect on reduced birth weight. Therefore, the relationship found is not merely correlational but rather approaches a causal relationship.

Furthermore, factors such as marital status and maternal education have been shown to significantly influence smoking behavior, and both can be considered important factors in explaining variations in this habit.

RECOMMENDATIONS

Based on the research results, several recommendations can be made:

1. Preventive measures and education for pregnant women are needed regarding the negative impacts of smoking on infant health, particularly regarding the risk of low birth weight.
2. Public health policies should place greater emphasis on controlling smoking behavior in pregnant women as part of programs to improve maternal and child health.
3. Improve access to and quality of education for women, as education level has been shown to play a role in reducing the likelihood of smoking behavior.
4. Future research is recommended to include other variables outside the model that could potentially influence birth weight, given the relatively low R-squared value.

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