

Assessing Effects of Exposures to DDE and PCBs on Premature Delivery via Ordinal Logistic Regression

Raphael Morsomme Rihui Ou Alessandro Zito

Case Study 1 - Stat 723

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Introduction

- **Framework:**

Dichlorodiphenyldichloroethylene (DDE) and Polychlorinated Biphenyls (PCBs) are chemicals that persist in the environment and get stored in fatty deposits in the human tissues.

⇒ Potential adverse effect on health

- **Question:**

Is exposure to DDE and PCBs associated with a higher chance of premature delivery in pregnant women?

Pregnancy timeline

- **Dangerous preterm:** delivery at 34 weeks or before (when main organs are underdeveloped)
- **Preterm:** delivery between 35 and 37 week
- **At term:** delivery after 37 weeks

Data collected by 12 centers contained gestational age (in weeks) of the mother, the DDE and PCBs concentration, socio-economic info and scores (race, occupation, education, income), amount of triglycerides and cholesterol in blood and smoking status.

Preprocessing:

- Drop obs. with gestational age > 45 (the world record)
- Standardize and average levels of PCBs¹

$$PCB_i = \frac{1}{11} \sum_{j=1}^{11} \frac{PCB_{ij} - \text{mean}_i(PCB_{ij})}{sd_i(PCB_{ij})}$$

- Mean impute of occupation, education and income scores
- Aggregate race into $race = 1$ if white and $race = 0$ if non-white

⇒ Total obs. = **2336**

¹This avoids the correlation between the PCBs. See the appendix.

- Our dependent variable is:

$$gestgroup_i = \begin{cases} 0 & \text{if Dangerous preterm} \\ 1 & \text{if Preterm} \\ 2 & \text{if At term} \end{cases}$$

- To account for triglycerides and cholesterol, we introduce an **adjusted measure for PCB and DDE** by:
 - ① Computing total lipids using Phillips et al.(1989) and Bernert et al.(2007) formula

$$lipid_i = 2.27 * cholesterol_i + triglycerides_i + 0.623$$

- ② Setting²

$$adjDDE_i = \frac{DDE_i}{\log(lipid_i)} \quad adjPCB_i = \frac{PCB_i}{\log(lipid_i)}$$

²The choice of the log comes from a Box-Cox analysis of the log-likelihood, as in Li, Longnecker and Dunson (2013)

EDA (I) - Exposures and gestational groups by race

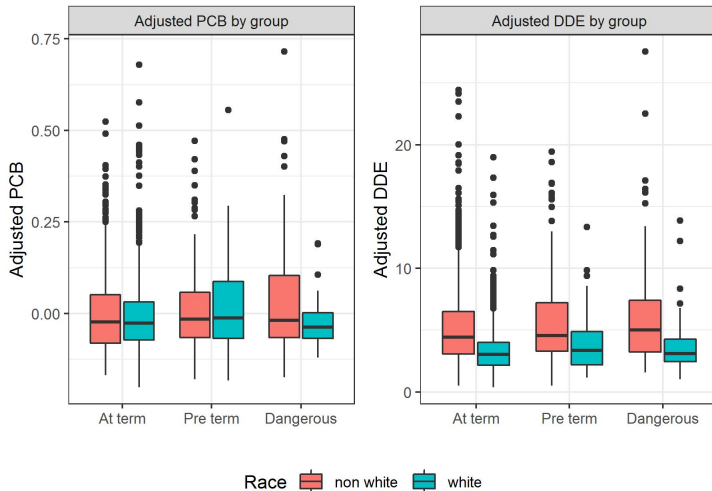


Figure: Relationship between delivery group and adjusted exposures, by race

EDA (II) - Exposure across centers

Model (I) - Ordinal Logistic Regression

We run the following ordinal logistic regression model:

$$\text{logit}(P(\text{gestgroup} \leq j)) = \beta_{0j} - \mathbf{X}\boldsymbol{\beta} + \epsilon$$

where $j = 0, 1, 2$ corresponds to the outcome level, and \mathbf{X} contains:

- *adjDDE*, *adjPCB*, *race*, *center*, *smoke*, the 3 scores, and mother age [main effects]
- (*adjDDE* + *adjPCB*) * (*race* + *center*) [interactions].

AIC-based backward variable selection:

- Maintain *DDE*, *PCB*, *smoke*, *center*, *race*, (*PCB* + *DDE*) * *race*
- Drop (*DDE* + *PCB*) * *center*, mother age,

Model assumptions are checked in the appendix.

Model (II) - Bayesian Ordinal Logistic Regression

Numerical Results

The interpretation of

Graphical Results

Conclusions

Appendix

More EDA

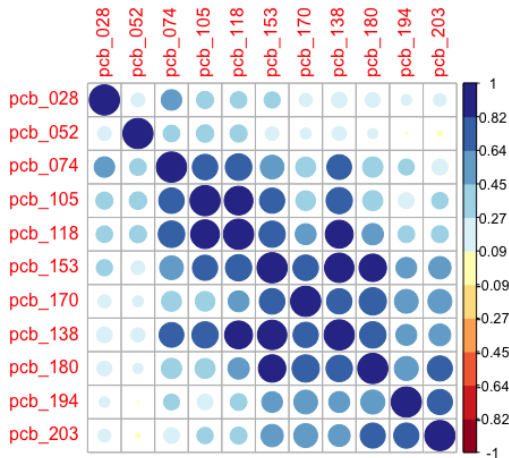


Figure: Correlation plot across PCBs

Appendix

Frequentist Model Checking

We can check the assumption of the (frequentist) ordinal logistic model by looking at the Surrogate residuals (Liu and Zhang, 2017).

If the model assumptions are correct, then the surrogate residuals R_S will have three properties:

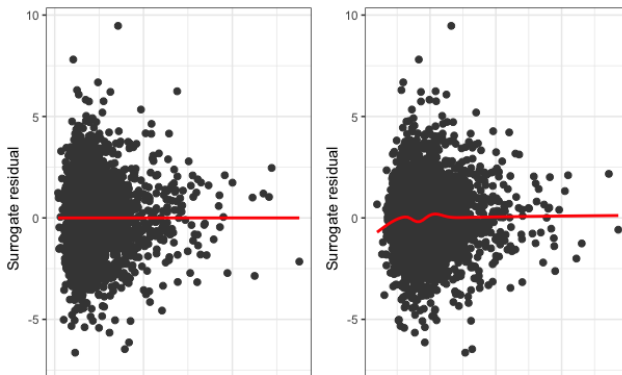
- 1 $E(R_S|X) = 0$
- 2 $Var(R_S|X) = c$, the conditional variance of R_S is constant
- 3 The empirical distribution of R_S resembles an explicit distribution that is related to the link function $G^{-1}(\cdot)$. Specifically,
 $R_S \sim G(c + \int u dG(u))$.

Appendix

Frequentist Model Checking

```
## Error in eval(lhs, parent, parent): object 'd' not found  
## Error in eval(expr, p): object 'd_subset' not found
```

Assumptions (i) and (ii) are checked with the Surrogate residuals plot. Both are satisfied in this case.



Appendix

Frequentist Model Checking

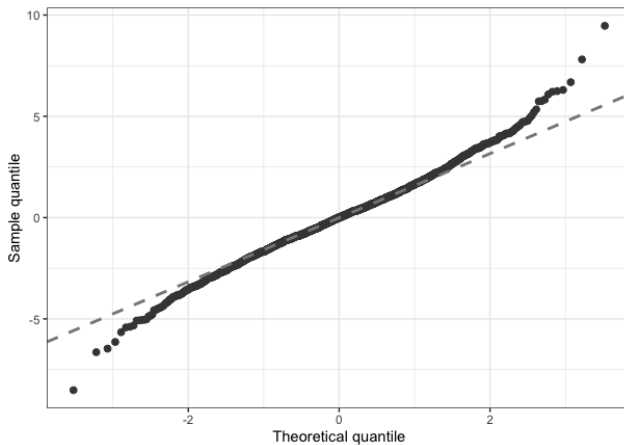


Figure: QQ plot of the Surrogate residuals

Appendix

Box-Cox transformation of lipid

Following Li, Longnecker and Dunson (2013), we adjust the exposures by dividing for a Box-Cox transformation of the level of lipids. We see that the optimal λ is at 0, which suggests a log transformation.

```
## Error in eval(lhs, parent, parent):  object 'd' not found
## Error in eval(expr, envir, enclos):  object 'd' not found
## Error in FUN(X[[i]], ...):  object 'log_likelihood' not found
```