

Mediation and Fuzzy Mediation Analysis for Multiple Covariates and Its Applications to Solar Power Data

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Abstract— In order to accurately analyze the relationship between variables affecting solar power, this paper propose mediation models using crisp and fuzzy data.

I. INTRODUCTION

As interest in renewable energy grows, many studies have been conducted to predict solar power. Unfortunately, there have been few papers taking into account the ambiguity of solar power generation. Since it is important to accurately understand the relationship between variables before prediction, this paper propose four models. Two of them are mediation models for multiple covariates if there is one mediator or multiple mediators. The other two are similar to the previous two models but use fuzzy variables. By setting weather data as independent variables, solar radiation as a mediator, and solar power as a dependent variable, this paper analyzes whether solar radiation mediates meteorological conditions with solar power. Plus, this study contrasts the models using crisp and fuzzy data then brings out statistical inference of total, direct, indirect effect.

II. METHODS AND RESULTS

Fuzzy Mediation Analysis with one mediator

When there are several independent variables, especially if those include vague information, a fuzzy mediation analysis model with one mediator can be proposed as follows:

$$\begin{aligned}\tilde{Y} &= \beta_{10} \oplus \beta_{11}\tilde{X}_1 \oplus \cdots \oplus \beta_{1p}\tilde{X}_p \oplus \tilde{E}_1, \\ \tilde{M} &= \beta_{20} \oplus \beta_{21}\tilde{X}_1 \oplus \cdots \oplus \beta_{2p}\tilde{X}_p \oplus \tilde{E}_2, \\ \tilde{Y} &= \beta_{30} \oplus \sum_{j=1}^p \beta_{31}^j \tilde{X}_j \oplus \beta_{32}\tilde{M} \oplus \tilde{E}_3,\end{aligned}$$

where $j = 1, \dots, p$.

Here, β_{1j} is the total effect of X_j on Y . $\beta_{2j}\beta_{32}$ is the indirect effect on Y through \tilde{X}_j and \tilde{M} , and β_{31}^j is the direct effect.

Easily checked, the following equation holds.

$$\beta_{1j} = \beta_{2j}\beta_{32} + \beta_{31}^j \quad (j = 1, \dots, p)$$

Fuzzy Mediation Analysis with multiple mediators

Moreover, if there are several mediators and all the variables are vaguely observed, then a fuzzy mediation analysis model with multiple mediators can be proposed as follows:

$$\begin{aligned}\tilde{Y} &= \beta_{10} \oplus \beta_{11}\tilde{X}_1 \oplus \cdots \oplus \beta_{1p}\tilde{X}_p \oplus \tilde{E}_1, \\ \tilde{M}_h &= \beta_{20} \oplus \beta_{21}^h\tilde{X}_1 \oplus \cdots \oplus \beta_{2p}^h\tilde{X}_p \oplus \tilde{E}_2, \\ \tilde{Y} &= \beta_{30} \oplus \sum_{j=1}^p \beta_{31}^j \tilde{X}_j \oplus \sum_{h=1}^k \beta_{32}^h \tilde{M}_h \oplus \tilde{E}_3,\end{aligned}$$

where $j = 1, \dots, p$ and $h = 1, \dots, k$.

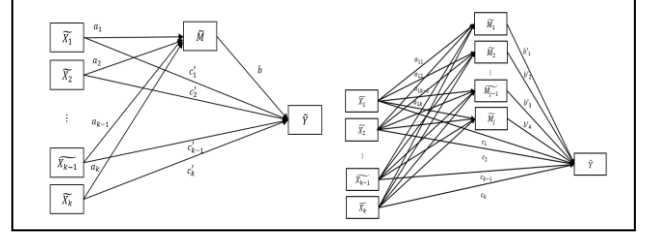


Figure 1. Fuzzy Mediation Analysis for Multiple Covariates with one mediator and multiple mediators

From the Table 1, the direct and indirect effect of the rain in weather information data does not significantly affect solar power in CMA(Crisp Mediation Analysis). On the other hand, in FMA(Fuzzy Mediation Analysis) they are significant.

Effect	Method	z(t)	p-value
Total	CMA	-4.348	<0.001
	FMA	-366.673	<0.001
Direct	CMA	-1.394	0.1633
	FMA	-895.365	<0.001
Indirect	CMA	-0.898	0.369
	FMA	184.145	<0.001

Table 1. Statistical inference about rain

III. CONCLUSION

Compared crisp and fuzzy mediation model, without considering the ambiguity of data, the overestimated or biased result could be derived. As a future study, model of this study will be broadened and used for mediation, moderation, mediation-moderation analysis.

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