CHAPTER 4

Modeling Dependence of Health Behaviors Using Copula-based Bivariate Ordered Probit

This chapter is developed from the original paper “Modeling Dependence of Health Behaviors Using Copula-based Bivariate Ordered Probit” by Suknark, Sirisrisakulchai and Sriboonchitta (2015) presented at the 8th Conference of the Thailand Econometric Society, published in “Causal Inference in Econometrics”, Springer International Publishing Switzerland. This paper can be found in the appendix B.

4.1. Introduction

Thailand is a medium-high income country where morbidity and mortality are primarily related to chronic rather than infectious diseases. Cardiovascular disease is the main cause of death with cancer as the next highest (WHO, 2014). The risk factors for raising the mortality rate were health behaviors. For example, alcohol consumption, smoking, poor eating habits and diet, urban air pollution, obesity, physical inactivity, and unsafe sex (Lopez et.al, 2006). Health behaviors are particularly important factors for health policy planning.

The explicit burden on society due to health-risk behaviors, particularly alcohol and tobacco consumption, includes health care costs, productivity loss, property damage costs, costs of criminal justice as well as law enforcement. To reduce health-risk behaviors, Thailand should aim to reduce alcohol consumption and prevent initiation of drinking. While Thailand already implements alcohol related policies, such as high alcohol taxation, restricted alcohol sale times, more effective measures at the societal level to control alcohol consumption and alcohol-related harms are still required. The national survey in 2011 reported that about 17.7 million people or 20.8%

of the population aged 15 years and over are alcohol users. Men used alcohol at a higher rate than women (The National Statistical Office, 2011).

Equally, tobacco consumption control policies have been implemented to reduce tobacco consumption and prevent initiation of smoking, especially in younger people. Current policies include high rates of tobacco taxation, control of tobacco advertising, non-smoking areas and bans on smoking in public places, workplaces, public transport, schools and other areas and facilities, supporting quit-smoking programs and publicity campaigns. These policies have been shown to be successful in decreasing the proportion of smokers in the Thai population (aged 15 years and older) from 32 % in 1991 to 20% in 2013 (The National Statistical Office, 2011).

Since 2010, the Thai Health Promotion Foundation has promoted physical activity in the Thai population by sponsoring and supporting several public campaigns nationally on the benefits of physical activity and advising people on the effective levels of frequency, duration and intensity required to achieve physical fitness. Such programs have also been supported at the local and regional level in many areas of the country. Most of the projects are mainly focused on increasing perceptions, attitudes, and practices related to physical activity generally (Katewongsa et al, 2014). The national survey in 2011 reported that about 26.1 % of the population played some form of sport or physical exercised, but this is actually a decrease of about 3 % when compared with the 2007 levels (The National Statistical Office, 2011).

The previous studies on the factors affecting alcohol consumption, tobacco consumption, and physical activity were based on a single equations (Katewongsa et al, 2014) (Suwannashote, 2009) (Praponsin, 2007) and (Sirirassamee, 2009). In this paper, we simultaneously determined the factors affecting each pair of some important health behaviors including alcohol-consumption and physical activity pair, tobacco-consumption and physical activity pair, and alcohol-consumption and tobacco-consumption pair, and attempted to quantify the dependence measures between these pairs using the copula approach. A bivariate ordered probit model was used to control for the common unobserved factors that might affect the random errors in each pair of health behaviors. If these random errors are ignored, and not correlated, inefficiency in parameter estimation is likely (Greene & Hensher, 2010). Moreover, understanding the dependencies between the ordinal choices for each pair of health behaviors will give information useful for designing more efficient health care programs.

4.2. Data

The data used in this study are from the Thai National Health Examination Survey, No.4 (NHES IV) from 2009. The data consists of a sample of 20,450 individuals. The ordered dependent variables are alcohol consumption (Y_1), tobacco smoking (Y_2), and physical activity in leisure time (Y_3). The independent variables are sex, age, income, chronic diseases, marital status, education level, and occupation. The alcohol consumption variable (Y_1) was stated as an amount of ethanol consumption on average per day in a year, and was classified into four levels: 0 for non-alcohol consumption; 1 for less than or equal to 40 grams of ethanol on average per day (considered to be a responsible level of consumption); 2 for 41 to 60 grams of ethanol on average per day (a harmful level); and 3 for over 61 grams of ethanol on average per day (hazardous level). For the tobacco consumption variable (Y_2), measured as an amount of cigarettes per day, it can be classified into four levels: 0 for non-smoking; 1 for up to 10 cigarettes per day; 2 for more than 10 and up to 20 cigarettes per day; 3 for more than 20 cigarettes per day. For the physical activity variable (Y_3), the levels of physical activity or exercise in leisure time were: 0 for non-physical activity; 1 for low level of activity; 2 for moderate level of activity; and 3 for high level of activity. Table 4.1. These are obviously indicative levels rather than attempting to quantify physical activity by number of hours or some other more precise measure. These values arising from the study are:

Table 4.1 Main statistics and description of variables

Variables	Description	N	Mean	SD	Mi	Max
Y1	Level of alcohol consumption	2045	0.446	0.697	0	3
Y2	Level of Tobacco consumption	2045	0.052	0.339	0	3
Y3	Level of Physical Activity	2045	2.201	0.845	0	3
Sex	1 if individual is male; 0 otherwise	2045	0.524	0.499	0	1
Age	In Year	2045	52.91	18.23	14	98
Income	In 1,000 Baht	2045	3.310	5.698	0	32,48
Bachelor	1 if individual graduated from Bachalor	2045	0.061	0.24	0	1
Agr	1 if individual works in agricultural sector;	2045	0.176	0.381	0	1
Whi	1 if individual is white-collar worker	2045	0.035	0.184	0	1
Police	1 if individual works as police or soldier; 0	2045	0.012	0.108	0	1
Labor	1 if individual is in labor sector; 0 otherwise	2045	0.480	0.499	0	1
Married	Marital status where 1 indicates married; 0	2045	0.636	0.481	0	1
Pe_bmi2	1 if individual has body mass index more	2045	0.348	0.476	0	1
Pe_tc200	1 if individual has chloresterol level more	2045	0.561	0.496	0	1
Qlhealth	Self health quality assessment, where 5 is	2045	3.708	0.867	0	5
NCD	Number of chronic diseases	2045	0.632	0.959	0	10

4.3 Copula-based Bivariate Ordered Probit Models

A Bivariate Ordered Probit Model is a system of two equations that can be used to model a simultaneous relationship of two ordinal outcome variables. The traditional Bivariate Ordered Probit Model uses the bivariate normal distribution to model the dependence between two equations (Greene & Hensher, 2010). In this study, we used a copula distribution function to model the dependence between two ordinal outcome responses. This is more flexible than the bivariate normal distribution. The Copula Function is a joint distribution with uniform margins. Let U_1,...,Uq be the possibly dependent uniform random variables on [0,1]-interval. Copula can be defined as

$$C_\theta(u_1,...,u_q) = \Pr(U_1 \le u_1,...,U_4 \le u_q), \qquad (1)$$

where C_θ(,...,) is a Copula Function with the dependent parameter θ, and μ_m, for m=1,...,q is a realization of U_m. The Copula Function must be grounded and increasing on the unit hypercube on its domain $[0,1]^q$ (see (Nelsen, 2006) for more details). By Sklar's Theorem (1959), for q marginal distribution functions, $F_1(.),...,F_q(.)$ and (z_1,...,zq) are arbitrary, we can derive the joint distribution H(,...,) for the random variables, $Z_1,...,Z_q$ as follows:

$$C_\theta(F_1(z_1),...,F_q(z_q)) = \Pr(F^{-1}(U_1) \le z_1,...,F^{-1}(U_q) \le z_q) \equiv H(z_1,...,z_q), \qquad (2)$$

where $Zm=F_j^{-1}$ (U_m), m=1,...,q. Thus, we can construct a joint distribution function from a set of margins by using the Copula Function to combine them.

Now we can start deriving our copula-based bivariate ordered probit model. Suppose that each individual i selects the level of two dependent ordinal responses based on the following system of two equations:

$$Y_{i1}^* = X_{i1}\beta_1 + \varepsilon_{i1}, \qquad (3)$$

$$Y_{i2}^* = X_{i2}\beta_2 + \varepsilon_{i2}, \qquad (4)$$

where i indexes individual i=1,...,N, Y_{i1}^* and Y_{i2}^* are latent variables, X_{i1} and X_{i2} are the K x N matrices of explanatory variables, β_1 and β_2 are conformable vectors of parameters to be estimated, and ε_{i1} and ε_{i1} are random errors.

We can model the observed level of two dependent ordinal responses, Y_{i1}, and Y_{i2} by the following threshold crossing conditions:

$$Y_{ij} = r_j \text{ if } \tau_{r_j,j} \le Y_{ij}^* < \tau_{r_j+1,j}, r_j = 1,\ldots,R_{j,}\ j = 1,2 \qquad (5)$$

where R_j are the number of ordinal levels of Y_ij and $\tau_{rj,j}$ are threshold parameters to be estimated from the model, with $\tau_{1,j} = -\infty$ and $\tau_{Rj,j} = +\infty$. The joint distribution of the individual selected the level of two ordinal response outcomes can be expressed as follows:

$$\Pr(\tau_{r_1,1} \le Y_{i1}^* < \tau_{r_1+1,1}, \tau_{r_2,2} \le Y_{i2}^* < \tau_{r_2+1,2})$$

$$= \Pr(\tau_{r_1,1} \le X_{i1}\beta_1 + \varepsilon_{i1} < \tau_{r_1+1,1}, \tau_{r_2,2} \le X_{i2}\beta_2 + \varepsilon_{i2} < \tau_{r_2+1,2})$$

$$= \Pr(\tau_{r_1,1} - X_{i1}\beta_1 \le \varepsilon_{i1} < \tau_{r_1+1,1} - X_{i1}\beta_1, \tau_{r_2,2} - X_{i2}\beta_2 \le \varepsilon_{i2} < \tau_{r_2+1,2} - X_{i2}\beta_2)$$

$$= C_\theta(F_1(\tau_{r_1+1,1} - X_{i1}\beta_1), F_2(\tau_{r_2+1,2} - X_{i2}\beta_2)) - C_\theta(F_1(\tau_{r_1,1} - X_{i1}\beta_1), F_2(\tau_{r_2+1,2} - X_{i2}\beta_2))$$

$$- C_\theta(F_1(\tau_{r_1+1,1} - X_{i1}\beta_1), F_2(\tau_{r_2,2} - X_{i2}\beta_2)) + C_\theta(F_1(\tau_{r_1,1} - X_{i1}\beta_1), F_2(\tau_{r_2,2} - X_{i2}\beta_2))$$

For the traditional Bivariate Ordered Probit Model, the marginal distribution $F_1(.)$ and $F_2(.)$ are specified as the standard normal distribution and the copula function is specified as a Gaussian copula. Therefore, the traditional Bivariate Ordered Probit Model is the special case of copula-based Bivariate Ordered Probit Model. To capture a wider range of dependencies and distributional shapes of random errors, we use different type of copula functions and a mixture of two normal components for random errors.

$$F_j(z) = \pi_j \phi\left(\frac{z - \mu_{j1}}{\sigma_{j1}}\right) + (1 - \pi_j)\phi\left(\frac{z - \mu_{j2}}{\sigma_{j2}}\right) \qquad (6)$$

The most general form of normal mixtures can be expressed as

where Φ is the standard normal distribution, π_j is the mixing parameter, μ_{j1} and μ_{j2} are location parameters, and σ_{j1} and σ_{j2} are dispersion parameters. The location and dispersion parameters have to be constrained to satisfy the mean and variance normalizations as follows:

$$\pi_j \mu_{j1} + (1 - \pi)\mu_{j2} = 0, \quad \pi_j (\sigma_{j1}^2 + \mu_{j1}^2) + (1 - \pi_j)(\sigma_{j2}^2 + \mu_{j2}^2) = 1 \qquad (7)$$

This normal mixtures distribution can capture the varieties of skewness or bimodality in the shape of random errors.

The log-likelihood of the copula-based Bivariate Ordered Probit Model is given by

$$\begin{aligned} LL = \sum \log \Big(& C_\theta\left(F_1(\tau_{r_1+1,1} - X_{i1}\beta_1), F_2(\tau_{r_2+1,2} - X_{i2}\beta_2)\right) \\ & - C_\theta\left(F_1(\tau_{r_1,1} - X_{i1}\beta_1), F_2(\tau_{r_2+1,2} - X_{i2}\beta_2)\right) \\ & - C_\theta\left(F_1(\tau_{r_1+1,1} - X_{i1}\beta_1), F_2(\tau_{r_2,2} - X_{i2}\beta_2)\right) \\ & + C_\theta\left(F_1(\tau_{r_1,1} - X_{i1}\beta_1), F_2(\tau_{r_2,2} - X_{i2}\beta_2)\right)\Big) \end{aligned}$$

The corresponding vector of parameters β_1, β_2, $\tau r_{1,1}$, $\tau r_{2,2}$, parameters of random errors π_1, μ_{11}, μ_{12}, σ_{11}, σ_{12}, π_2, μ_{21}, μ_{22}, σ_{21}, σ_{22}, and dependence parameter θ can be estimated simultaneously using the maximum likelihood estimation. This study uses STATA software (STATA) and user written command BICOP (Hernandez and Pudney 2015) to estimate all parameters in the models.

4.4 Empirical Results

We consider both Frank copula and Gaussian copula that allow for both positive and negative dependence. For the marginal distribution of each residual, we consider three specifications including specifying each marginal as a standard normal distribution, and specifying one of the random errors as a normal-mixture distribution and another as a standard normal distribution, and specifying each marginal as a normal-mixture distribution. For all three pairs, the best fitted model (in terms of Akaike Information Criteria, AIC) is the Frank copula with standard normal distribution for both random errors. In comparison with the two separate univariate ordered probit model (independent copula), we found that the estimated standard errors of bivariate models are lower than those of univariate models (the results are not shown here). However, the differences are very small (five digits after the decimal point) corresponding with the low level of correlation between each random error.

4.4.1 Factors Affecting Alcohol Consumption and Physical Activity Behaviors

Table 4.2 presents the model estimation results for the level of alcohol consumption and physical activity behaviors pair. The first dependent variable to be discussed is alcohol consumption level. The explanatory variables included in the model that significant are age, income, high cholesterol, gender, non-communication diseases, occupation, education, and Body Mass Index. The coefficient interpretations are: 1) young individuals, individuals with higher income, individuals with lower cholesterol of 200 mg/dl or a lower number of chronic diseases, individuals who have education lower than bachelor degree, and individuals who are non-obese (BMI < 25) are more likely to alcohol consumption; 2) males are more likely to consume alcohol than females; 3) individuals who work in the agricultural sector and work in risky occupations such as police and soldiers are more likely to consume alcohol than white-collar workers and those from the labor sector.

Table 4.2 Parameter estimates for level of alcohol consumption
and level of physical activity model

Variables	Y1		Y3	
	Coeff.	Std.err	Coeff.	Std.err
Sex	0.956	0.019	0.143	0.017
Age	-0.012	0.001	-0.005	0.001
Income	1.48E-05	1.71E-06	-2.40E06	1.60E-06
bachelor	-0.08	0.042	0.035	0.038
Agr	0.249	0.031	0.523	0.027
Whi	0.179	0.057	0.125	0.052
police	0.251	0.079	0.194	0.077
labor	0.168	0.027	0.339	0.023
married	0.025	0.02	0.097	0.018
pe_bmi25	-0.034	0.02	0.059	0.018
pe_tc200	-0.062	0.019	-0.053	0.017
qlhealth	-0.011	0.011	0.09	0.009
NCD	-0.12	0.011	-0.041	0.009
τ_1	-1.626	0.072	-2.244	0.068
τ_2	-0.135	0.071	-0.576	0.064
τ_3	0.107	0.071	0.205	0.064
θ	0.623	0.060		
LL		-35,863.919		

The second dependent variable is physical activity level. The explanatory variables included in the model that are significant are age, high cholesterol, health quality assessment, gender, non-communicable diseases, occupation, married status, and Body Mass Index. The coefficient interpretations are: 1) young individuals, individuals with higher health quality assessment, individuals with lower cholesterol of 200 mg/dl or lower, number of chronic diseases, individuals who are married, and individuals who are non-obese (BMI < 25) are more likely to undertake physical activities; 2) males are more likely to undertake physical activities than females; 3) individuals who work in the agricultural sector are more likely to undertake physical activities than those from the other sectors.

4.4.2 Factors Affecting Tobacco Consumption and Physical Activity Behaviors

Table 4.3 presents the model estimation results of tobacco consumption and physical activity behaviors. For the first dependent variable, namely, the level of tobacco consumption, the explanatory variables included in the model that significant are age, quality of health assessment, gender, non-communication diseases, occupation only agriculture and labor, married, and Body Mass Index. The coefficient interpretations are: 1) Young individuals, individuals who lower health quality assessment or lower number of chronic diseases, individuals who education lower than bachelor degree, and individuals who non-obese (BMI < 25) are more likely to tobacco consumption; 2) male are more likely to alcohol consumption than female; 3) individuals who work in agricultural sector are more likely to tobacco consumption than labor sector.

For the second dependent variable, which is physical activity level, the explanatory variables included in the model that significant are age, high cholesterol, health quality assessment, gender, non-communication diseases, occupation, married status, and Body Mass Index. The coefficient interpretations are: 1) Young individuals, individuals who higher health quality assessment, individuals who lower cholesterol 200 mg/dl or lower number of chronic diseases, individuals who married, and individuals who non-obese (BMI < 25) are more likely to physical activities; 2) male are more likely to physical activities than female; 3) individuals who work in agricultural sector and labor are more likely to physical activities than the other sector.

Table 4.3 Parameter estimates for level of tobacco consumption
and level of physical activity model

Variables	Y2		Y3	
	Coeff.	Std.err	Coeff.	Std.err
Sex	1.426	0.088	0.143	0.017
Age	-0.009	0.002	-0.005	0.001
Income	5.70E-06	3.85E-06	-2.40E-06	1.64E-06
bachelor	-0.533	0.131	0.035	0.038
Agr	0.259	0.072	0.523	0.027
Whi	0.048	0.159	0.124	0.052
police	0.135	0.156	0.194	0.077
labor	0.161	0.069	0.339	0.023
married	-0.06	0.049	0.097	0.018
pe_bmi25	-0.157	0.05	0.06	0.018
pe_tc200	0.06	0.043	-0.053	0.017
qlhealth	-0.098	0.024	0.09	0.009
NCD	-0.08	0.029	-0.041	0.009
τ_1	-0.569	0.174	-2.244	0.068
τ_2	-0.413	0.174	-0.576	0.064
τ_3	0.051	0.176	0.205	0.064
θ	-0.528	0.170		
LL	-23,904.808			

4.4.3 Factors Affecting Alcohol Consumption and Tobacco Consumption Behaviors

Table 4.4 presents the model estimation results of alcohol consumption and tobacco consumption behaviors. The estimated parameters are similar to the previous subsections. More information from Table 4.4 is just the dependence parameter estimation, which will be discussed in the next subsection. The marginal effects of each dependent variable are shown in Table 4.5 to Table 4.7.

4.4.4 Dependence Measures of Health Behaviors Pairs

The dependence parameters for three different pairs are significant, indicating the need to model these behaviors simultaneously. The dependence parameter estimated from the Frank copula bivariate ordered probit for alcohol consumption and physical activity behaviors is 0.623. This dependence parameter can be interpreted as a concordance measure (Kendall's tau) equal to 0.07. The dependence parameter estimated from the Frank copula bivariate ordered probit for tobacco consumption and physical activity behaviors is -0.528. This dependence parameter can be interpreted as a concordance measure (Kendall's tau) equal to -0.06. For the parameter estimated from the Frank copula bivariate ordered probit for alcohol consumption and tobacco consumption behaviors, the dependence parameter is 0.979, corresponding with 0.108 as the concordance measure. The concordance measure for all three models are quite small but statistically significant. Thus, we can not ignore these dependencies in model estimation.

Table 4.4 Parameter estimates for level of alcohol consumption and level of tobacco consumption model

Variables	Y1		Y2	
	Coeff.	Std.err	Coeff.	Std.err
Sex	0.956	0.019	1.429	0.088
Age	-0.012	0.001	-0.009	0.002
Income	1.48E-05	1.71E-06	5.00E-06	3.87E-06
bachelor	-0.081	0.042	-0.529	0.131
Agr	0.249	0.031	0.263	0.072
Whi	0.182	0.057	0.046	0.158
police	0.253	0.079	0.154	0.155
labor	0.169	0.028	0.156	0.069
married	0.025	0.02	-0.056	0.05
pe_bmi25	-0.034	0.02	-0.15	0.05
pe_tc200	-0.062	0.019	0.066	0.043
qlhealth	-0.01	0.011	-0.1	0.024
NCD	-0.12	0.011	-0.081	0.029
τ_1	-1.622	0.072	-0.581	0.175
τ_2	-0.131	0.071	-0.425	0.175
τ_3	0.111	0.071	0.039	0.176
θ	0.979	0.178		
LL		-17,171.767		

Table 4.5 Marginal Effects for Level of Alcohol Consumption

Variables	Level of Alcohol Consumption			
	Level 0	Level 1	Level 2	Level 3
Age	0.0037	-0.0026	-0.0003	-0.0008
Income	-4.65E-06	3.28E-06	4.13E-07	0.000000957
pe_tc200	0.0195	-0.0138	-0.0017	-0.004
qlhealth	0.0033	-0.0023	-0.0003	-0.007
sex	-0.3007	0.2119	0.0267	0.0621
NCD	0.0377	-0.0266	-0.0033	-0.0078
Agr	-0.0786	0.0554	0.007	0.0162
Whi	-0.0573	0.0404	0.0051	0.0118
Police	-0.0792	0.0558	0.007	0.0164
Labor	-0.0533	0.0375	0.0047	0.0111
Married	-0.0077	0.0054	0.0007	0.0016
Bachelor	0.0255	-0.018	-0.0022	-0.0053
Pe_bmi25	0.0109	-0.0077	-0.001	-0.0022

Table 4.6 Marginal Effects for Level of Tobacco Consumption

Variables	Level of Alcohol Consumption			
	Level 0	Level 1	Level 2	Level 3
Age	0.0005	-0.0001	-0.0002	-0.0002
Income	-3.14E-07	7.19E-08	1.44E-07	9.81E-08
pe_tc200	-0.0034	0.0008	0.0015	0.0011
qlhealth	0.0052	-0.0012	-0.0024	-0.0016
sex	-0.0753	0.0172	0.0344	0.0237
NCD	0.0042	-0.0009	-0.0019	-0.0014
Agr	-0.0136	0.0031	0.0062	0.0043
Whi	-0.0017	0.0004	0.0008	0.0005
Police	-0.0068	0.0016	0.0031	0.0021
Labor	-0.0082	0.0019	0.0037	0.0026
Married	0.0031	-0.0007	-0.0014	-0.001
Bachelor	0.0281	-0.0064	-0.0128	-0.0089
Pe_bmi25	0.0081	-0.0019	-0.0037	-0.0025

Table 4.7 Marginal Effects for Level of Physical Activity

Variables	Level of Alcohol Consumption			
	Level 0	Level 1	Level 2	Level 3
Age	0.0002	0.0014	0.0004	-0.002
Income	7.00E-08	6.53E-07	1.85E-07	-9.08E-07
pe_tc200	0.0016	0.0147	0.0041	-0.0204
qlhealth	-0.0026	-0.0246	-0.0069	0.0341
sex	-0.0042	-0.0392	-0.0111	0.0545
NCD	0.0012	0.0113	0.0032	-0.0157
Agr	-0.0154	-0.1433	-0.0405	0.1992
Whi	-0.0036	-0.0339	-0.0096	0.0471
Police	-0.0057	-0.0534	-0.0151	0.0742
Labor	-0.0099	-0.0929	-0.0262	0.129
Married	-0.0028	-0.0265	-0.0075	0.0368
Bachelor	-0.001	-0.0097	-0.0027	0.0134
Pe_bmi25	-0.0017	-0.0162	-0.0046	0.0225

4.5 Discussion and Conclusion

From the empirical results previously discussed, the followings are the recommended policies designed to reduce health-risk behavior and increase health inducing behavior for Thai citizens:

a) Campaigns aimed at reducing alcohol consumption should have a greater focus on workers in the agricultural sector and in risky occupations.

b) The empirical results show that there is a negative correlation between tobacco consumption behavior and physical activity behavior. Thus, anti-smoking policies would have a more positive impact when the policy makers promote physical activity campaign.

c) Finally, the empirical results confirm that there is some dependence between alcohol and tobacco consumption as discussed in the Alcohol Alert (U.S. Department of Health and Human Services, 2007). This study found that people who smoke are much more likely to drink, and people who drink are much more likely to smoke. Thus, the alcohol consumption reduction policies and anti-smoking policies would have more positive impact when they are more closely associated.

For further study, the copula-based ordered probit model should be generalized to a multivariate model. However, the main concern on this issue is the curse of dimensionality. When the level of ordinal outcomes and the number of outcomes itself increase, it will give more computational burden on model estimation. Practitioners have to consider about the trade-off between computational cost and efficiency gain.