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Propensity Scoreusing Logistic Regression on HIV/AIDS Case in Surabaya City

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ABSTRACT

Propensity score is a conditional probability that has a certain treatment by involve the observed covariate. This method use to decrease the bias estimation from treatment effect on observation data because of the confounding factor. In observational research, there is unbalance covariate between treatment group and control group. Stratification, matching or weighting used in propensity score to clear up the confounding. If the treatment binary, logistic and probit regression model with covariate variable basis from regression prediction used propensity score. In this research, the data from Surabaya's Orbit about the influence factors of HIV/AIDS on inject drugs user. Always using condom variable as the confounding variable where the treatment is always using condom, while the response variable is HIV/AIDS status. The propensity score use logistic regression because the confounding variable binary. Propensity score use weighted observation unit. Estimation of propensity score use logistic regression by Maximum Likelihood Estimator, and to be continued by Newton-Raphson iteration. Then check the balance between treatment group and control group. If the group balance, do the confounding variable significantly test and interpretation. The result of weighted propensity score on HIV/AIDS case is inject drugs user who always use condom can infected 1.25 times more than not always use condom.

KEY WORDS: *HIV/AIDS, weighting, propensity score, logistic regression.*

1. INTRODUCTION

Rosenbaum and Rubin was the first to proposed propensity score in 1983.This method use to decrease the bias estimation from treatment effect on observation data because of the confounding factor. In observational research, there is unbalance covariate between treatment group and control group. that the bias is reduced when the comparison of outcomes is performed using treated and control subjects who are as similar as possible[1].

That method base on propensity score using to removethis imbalance. There are four methods based on propensity score that is stratification, matching, covariate adjustment and inverse probability weighting by propensity score. The popular method used to estimation average treatment effect is showed by [2], which observation unit is classified by propensity score estimation and distinct of estimation as average treatment effect os subclasses. An alternative approach is to adjust for confounding by using estimated propensity scores to construct weights forindividual observations[3]. When treatment is binary, we can use a logisticor probit model with the baseline variables as covariates and take the predicted value from the regression as the subject's propensity score [4]. For these reasons, the logistic regression has become the most frequently use technique to estimate the propensity score because it is easily to interpretation.Logistic regression outcome can use to calculate propensity score[5]. Logistic regression models are commonly used in observational research to assess the relationship between a certain exposure or treatment and a dichotomous outcome (response variable), while ''controlling for'' confounders and effect modifiers (explanatory variables) to ensure comparability between the groups and to reduce bias [6].

Inject drugs user has confronted two risks to be infected HIV/AIDS. The first risk comes when you use infected needle and syringe together. The second risk comes whe you havea sex with more than 1 person and without using condom [7]. The exist combination of infection risk factor HIV/AIDS caused confounding. Confounding effect in predictor variabel is reduced by propensity score.Accordingly, this research proposed to analyze propensity score using logistic regression on HIV/AIDS case in one of city where the highest infected HIV/AIDS is Surabaya City.

2. LITERATURE RIVIEW

Propensity Score

Rosenbaum dan Rubin (1983)introduced *propensity score*for $i = 1, 2, \cdots, n$ as the conditional probability which is depended on probability treatment unit $(Z_i = 1)$ and then compared to control unit $(Z_i = 0)$ with the observed covariatevector x_i :

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$$e(x_i) = \mathrm{P}(Z_i = 1 | X_i = x_i) \quad (1)$$

The first and perhaps the most critical step in employing a propensity score adjustment is to select a set of covariates (or potential confounders) from which to estimate the propensity score. This selection process should be made a-priori on theoretical grounds and based on previous available empirical evidence about relationships between variables of interest.[8]. Chi square test used to check relationship between variables.

Logistic Regression

Logistic regression with the confounder as the outcome and dummy variables for the treatment levels as the predictors[9]. Randomly and dicotumous Y responsevariable has the value of 1 with the π probabilityis 0.1-πprobability is called as*point-binomial*[10].Logistic regression model with k predictor variable according to the following formula:

$$\pi(x) = \frac{\exp\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_j\right)}{1 + \exp\left(\beta_0 + \sum_{j=1}^{k} \beta_j x_j\right)} \quad (2)$$

***Propensity Score* using Logistic Regression**

The propensity score for each subject can be estimated with different methods including discriminant analysis and even classification trees. The most common methodinuse. Based on equation (1), propensity score used logistic regression model that respon variable is binary where $Z_i = 1$ if treated and $Z_i = 0$ if control. The result of logistic regression can then be used to calculate the propensity score according to the following formula [5]:

$$e(x_i) = \frac{\exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)} \quad (3)$$

where:

β_0: intercept

$\beta_1, \beta_2, \cdots, \beta_k$: regression coefficient

$x_1, x_2, \cdots, x_k$: predictor variables.

Propensity Score Weighting

Propensity score can be used to weight the obsevasional when estimating the treatment effect. To estimate $E(y_0 | z = 1)$, let participant *i* in the control sample have weight $w_i = e(\mathbf{x}_i) / (1 - e(\mathbf{x}_i))$, the odds that a randomly selected participant with feature $\mathbf{x}$ would go to the treatment. We observe $y_i = y_{1i}$ if participant *i* is in the treatment group and $y_i = y_{0i}$ if participant *i* is in control group.

Propensity Score Evaluation

The quality of the adjustment for the observed covariates achieved by propensity score weighting is easy to valuate. The estimated propensity score weights should equalize the distributions of the cases. This implies that weighted statistics of the covariates of the comparison group should equal the same statistics for the treatment group. To assess the quality of the propensity score weights one could compare a variety of statistics is such as means, medians, variances, and Kolmogorov-Smirnov statistics for each covariate as well as interactions[11].

HIV/AIDS

Injected Napza is napza which is injected into the body in order to acelerate the reaction. It is done because of economic reason, its efficiency, solidarity and life style [12]. People belived that it would be more efficent to inject napza than to burn it[12].

AIDS patient is classified into two catagories. First, a patient who is infected HIV and showing clinical symptoms (AIDS patient). Second, a patient who is infected HIV but not showing clinical symptoms (HIV patient). The incubation period of this disease is about 5 years or more, start from the infection until showing clinical symptoms. It is believed that HIV infection will last for life [13].

The following are some factors that affect penasun to be infected AIDS:

1. Gender

   A man is easier to be infected HIV/AIDS compared to a woman. It is beacause of the difference in life style between a man and a women [14].

2. Education
   One of the ways to control this HIV/AIDS is by preventing yourself getting infected or infenting someone else. Because the higer education that someone take, the more knowledge that someone have, the better preventing step that someone take to be not infected by HIV/AIDS virus [14].
3. Fixed couple
   Fixed couple is a long-term relationship between two people with some sexual acitivies and other privacy commitment in it [15].
4. Unfixed couple
   Unfixed couple is a short-term relationship with no emotional feelings nor further commitment in it. A women who is willing to have this kind of relationship called aslave and involved others risk attitude (such as using injected napza, not always used condom) [14].
5. The Use of Condom
   Other sex habits which risk the penasun is having sex without using condom. Most of penasun have been infected HIV virus. And with this sex habits will expand the patient of HIV/AIDS. By not sharing the same syringe together or using condom when having sex activities will prevent the spread of HIV/AIDS not only to the user of injected napza but also to a group who have risky sexual habits [16].
6. The use of unstrerilized syringe
   Sharing the same unsterilized syringe together has been increasing the number of HIV patient. Some research in many different countries have proved that this habits is susceptible to be infected by HIV virus and other disease through the unsterilized syringe [17].

3. METHODOLOGY

Research Method

1. To estimate*propensity score*using logistic regression
   a. Let probability distribution for data set $\left(x_i, \mathrm{z}_i\right)$, $f\left(x_i\right)=e\left(x_i\right)^{z_i}\left(1-e\left(x_i\right)\right)^{n-z_i}$,
      where
      $$e\left(\mathbf{x}_i\right)=\frac{\exp\left(\boldsymbol{\beta}'\mathbf{x}_i\right)}{\left[1+\exp\left(\boldsymbol{\beta}'\mathbf{x}_i\right)\right]},$$
   b. Determine likelihood function, jointly probabilitas function.
   c. Maximize ln *l(*$\boldsymbol{\beta}$*)* or ln *likelihood*.
   d. Derivative *L(*$\boldsymbol{\beta}$*)* of $\boldsymbol{\beta}$ and equals to zero.
   e. $\boldsymbol{\beta}$ is estimated by nuerical method because nonlinear model. So, we can used Newton Raphson iteration method.
2. Application of propensity score used for sufferer of HIV/AIDS that the steps are:
   a. Descriptive statisticfor data with graphics anda cross tabulation based on variables.
   b. Determine confounding variable, and next it denote *z*withparameter.
   c. Calculate propensity score estimation what has been gotten from first step.
   d. Weighting for*propensity score*.
   e. Balancing withtested what propensity score of treatment and control group have equal distribution for each covariate.
   f. Significant test and interpretation of confounding variable.

Data Source& Variables

The data which is used in this study is secondary data, cases of people with HIV/AIDS which is surveyed by LSM ORBIT Surabaya City in 2013. Respon variable are HIV/AIDS's status (0 =negative, 1=positif). Predictor variables, x_1 isgender (1=male, 2= female), x_2 is age, x_3 iseducation (1=never school, 2=SMP, 3=SMA, 4=PT, 5=not answer), x_4 is income (1=< 500.000, 2=500.000-1.000.000, 3=>1.000.000, 4=not answer), x_5 is married (1=married, 2=divorced, 3=never divorce, 4=not answer), x_6 isfixed couple (1=man, 2=woman, 3 =nothing), x_7 is not fixed couple (1=man, 2=woman, 3=man and woman, 4 = nothing), x_8 is always use condom (1=yes and 2=no), x_9 is injected drug (1=putau, 2=buphre, 3=anti depresan, 4=mixture), x_{10} is injection frequency (1=1-3 times/day, 2=1-3 times/week, 3=1-3 times/month), x_{11} is sharing the unsterilized syringe (1=yes, sterilized 2=yes, not sterilized, 3=never), x_{12} is always using sterilized syringe (1=yes, 2=no) dan x_{13} always using your own syringe (1=yes, 2=no).

4. RESULTS AND DISCUSSION

4.1 Propensity Score Estimation

Propensity score estimation using logistic regression with MLE mwthod is estimated parameter model. Let probability distribution for dataset (x_i, z_i) where z_i as confounding variable:

$$f(x_i) = e(x_i)^{z_i} \left(1 - e(x_i)\right)^{n - z_i},$$

Where $e(x_i)$ can write on matrix:

$$e(\mathbf{x}_i) = \frac{\exp\left[(\boldsymbol{\beta}'\mathbf{x}_i)\right]}{1 + \exp\left[(\boldsymbol{\beta}'\mathbf{x}_i)\right]},$$

Where $\boldsymbol{\beta} = (\beta_0 \quad \beta_1 \quad \beta_2 \quad \cdots \quad \beta_k)$, $\mathbf{x}_i' = (1 \quad x_{i1} \quad x_{i2} \quad \cdots \quad x_{ik})$.

between observation assumed independent, so likelihood function is proportional to the product of *n*binomial functions,

$$l(\boldsymbol{\beta}) = \prod_{i=1}^{n} e(\mathbf{x}_i)^{z_i} \left(1 - e(\mathbf{x}_i)\right)^{n - z_i}$$

$$l(\boldsymbol{\beta}) = \left\{ \prod_{i=1}^{n} \exp\left[\log\left(\frac{e(\mathbf{x}_i)}{1 - e(\mathbf{x}_i)} \right)^{z_i} \right] \right\} \left\{ \prod_{i=1}^{n} \left(1 - e(\mathbf{x}_i)\right)^{n} \right\}$$

$$l(\boldsymbol{\beta}) = \left\{ \exp\left[\sum_{i=1}^{n} z_i \boldsymbol{\beta}'\mathbf{x}_i \right] \right\} \left\{ \prod_{i=1}^{n} n\left[1 + \exp(\boldsymbol{\beta}'\mathbf{x}_i)\right]^{-1} \right\},$$

the log likelihood equals

$$L(\boldsymbol{\beta}) = \left(\sum_{i=1}^{n} z_i \boldsymbol{\beta}'\mathbf{x}_i \right) - \sum_{i=1}^{n} n \log\left[1 + \exp(\boldsymbol{\beta}'\mathbf{x}_i)\right].$$

because z_i isbinary ($z_i = 1$ if treatment and $z_i = 0$ if control), so process estimation devide

- For treatment group $z_i = 1$

  $$L(\boldsymbol{\beta}) = \sum_{i=1}^{n} \boldsymbol{\beta}'\mathbf{x}_i - \sum_{i=1}^{n} n \log\left[1 + \exp(\boldsymbol{\beta}'\mathbf{x}_i)\right].$$

  The next step, maximize log likelihood with derivate $L(\boldsymbol{\beta})$ of β_j and equals to zero.

  $$\frac{\partial L(\boldsymbol{\beta})}{\partial \beta_a} = 0$$

  $$\sum_{i=1}^{n} \mathbf{x}_{ia} - \sum_{i=1}^{n} n\hat{e}(\mathbf{x}_i) x_{ia} = 0, \quad a = j = 0, 1, 2, \cdots, k.$$

  With $\hat{e}(\mathbf{x}_i) = \dfrac{\exp\left(\hat{\boldsymbol{\beta}}'\mathbf{x}_i\right)}{1 + \exp\left(\hat{\boldsymbol{\beta}}'\mathbf{x}_i\right)}$ is explainedestimation $e(\mathbf{x}_i)$ by MLE. Because the result of first differential is not closed form,

  β_j is estimated by Newton Raphson what is according to the following formula:

  $$\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} - \left(\mathbf{H}^{(t)}\right)^{-1} \mathbf{q}^{(t)}; t = 1, 2, \cdots \text{ until convergence}$$

  So,

  $$\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} + \left\{ \mathbf{X}' Diag\left[n\hat{e}(\mathbf{x}_i)^{(t)} \left(1 - \hat{e}(\mathbf{x}_i)^{(t)}\right) \right] \mathbf{X} \right\}^{-1} \mathbf{X}' \left(1 - \boldsymbol{m}^{(t)}\right) \text{ where } \mathbf{m}^{(t)} = n\hat{e}(\mathbf{x}_i)^{(t)}.$$

For control group $z_i = 0$

$$L(\boldsymbol{\beta}) = -\sum_{i=1}^{n} n \log\left[1 + \exp\left(\boldsymbol{\beta}'\mathbf{x}_i\right)\right].$$

The next step, maximize log likelihood with derivate $L(\boldsymbol{\beta})$ of β_j dan equals to zero.

$$\frac{\partial L(\boldsymbol{\beta})}{\partial \beta_a} = 0$$

$$-\sum_{i=1}^{n} n\hat{e}\left(\mathbf{x}_i\right) x_{ia} = 0, \quad a = j = 0,1,2,\cdots,k.$$

With $\hat{e}\left(\mathbf{x}_i\right) = \dfrac{\exp\left(\hat{\boldsymbol{\beta}}'\mathbf{x}_i\right)}{1+\exp\left(\hat{\boldsymbol{\beta}}'\mathbf{x}_i\right)}$ is explained estimation $e\left(\mathbf{x}_i\right)$ by MLE. Because the result of first differential is not closed form, β_j is estimated by Newton Raphson what is according to the following formula:

$$\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} - \left(\mathbf{H}^{(t)}\right)^{-1}\mathbf{q}^{(t)}; t = 1,2,\cdots \text{ until convergen}$$

So,

$$\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} + \left\{\mathbf{X}'Diag\left[n\hat{e}\left(\mathbf{x}_i\right)^{(t)}\left(1-\hat{e}\left(\mathbf{x}_i\right)^{(t)}\right)\right]\mathbf{X}\right\}^{-1}\left(-\mathbf{X}'\boldsymbol{m}^{(t)}\right) \text{ where } \mathbf{m}^{(t)} = n\hat{e}\left(\mathbf{x}_i\right)^{(t)}.$$

After we get $\mathbf{H}$ and $\mathbf{q}$ so do iteration with following step are:

1. Determine starting value of $\hat{\boldsymbol{\beta}}$ when the first iteration is $\hat{\boldsymbol{\beta}} = \mathbf{0}$.
2. Starting from the first iteration or $t = 0$, then we do iteration with calculate $\boldsymbol{\beta}^{(t+1)} = \boldsymbol{\beta}^{(t)} - \left(\mathbf{H}^{(t)}\right)^{-1}\mathbf{q}^{(t)}$.
3. If $\left\|\boldsymbol{\beta}^{(t+1)} - \boldsymbol{\beta}^{(t)}\right\| \le \Theta$ when Θ is very small number so stopped iteration and get the estimation, if not so repeat previous step.

4.2 Propensity Score Analysis

1. Select A Confounding Variable

The relationship between a variable showing behavior patterns with a variable showing the utilization of syringe shows the confunding variable. The result of chi square test shows that always use condom variable has a relationship with the 2 other vaiables (always use sterilized syring and always use your own syringe). Whereas a variable of marriage status (fixed couple and unfixed couple) has a relationship with one variable of utilization of syringe. So that we choose always use condom variable as the confunding variable.

2. Propensity Score Model

$$e\left(x_i\right) = \frac{\exp\left(k\right)}{1+\exp\left(k\right)}$$

where

$$\begin{aligned} k = {} & -12,573 + 2,334x_1 + 0,047x_2 - 17,383x_{3.1} - 2,063x_{3.2} \\ & +0,098x_{3.3} + 4,274x_{3.4} - 16,205x_{4.1} + 2,961x_{4.2} + 0,550x_{4.3} \\ & -1,122x_{5.1} - 19,526x_{5.2} - 0,734x_{5.3} + 1,135x_{6.1} + 1,159x_{6.2} \\ & +3,345x_{7.1} + 1,880x_{7.2} - 18,762x_{7.3} + 1,846x_{9.1} - 16,381x_{9.2} \\ & -15,921x_{9.3} - 0,588x_{10.1} + 0,301x_{10.2} + 2,149x_{11.1} \\ & -0,690x_{11.2} + 1,312x_{12} + 1,127x_{13} \end{aligned}$$

3. Propensity Score Evaluation

Hypotesis

$\mathrm{H}_0 : F_T\left(\hat{e}\left(x_{ij}\right)\right) = F_C\left(\hat{e}\left(x_{ij}\right)\right)$ for all $\hat{e}\left(x_{ij}\right)$ $\mathrm{H}_1 : F_T\left(\hat{e}\left(x_{ij}\right)\right) \neq F_C\left(\hat{e}\left(x_{ij}\right)\right)$

Significant level: $\alpha = 5\%$.

Staistics Test: KS=max$\left|S_T\left(x_{ij}\right) - S_C\left(x_{ij}\right)\right|$

$S_T\left(x_{ij}\right)=\left(\text{number of } \hat{e}_T\left(x_{ij}\right) \text{ observed} \le x_{ij}\right)\Big/ n_T$ and $S_C\left(x_{ij}\right)=\left(\text{number of } \hat{e}_C\left(x_{ij}\right) \text{ observed} \le x_{ij}\right)\Big/ n_C$

Critical region: Reject H_0 withsignificant levelαif $KS_{count} > KS_{table}$ where $KS_{table} = 0,3435$

Decision:

Table 1.*Balancing*Coavariates

Variables	KS_{count}	Variables	KS_{count}
x_1	0.00	$x_{6(2)}$	0.00
x_2	0.14	$x_{7(1)}$	0.00
$x_{3(1)}$	0.00	$x_{7(2)}$	0.02
$x_{3(2)}$	0.01	$x_{7(3)}$	0.00
$x_{3(3)}$	0.04	$x_{9(1)}$	0.09
$x_{3(4)}$	0.04	$x_{9(2)}$	0.00
$x_{4(1)}$	0.00	$x_{9(3)}$	0.00
$x_{4(2)}$	0.07	$x_{10(1)}$	0.05
$x_{4(2)}$	0.11	$x_{10(2)}$	0.01
$x_{5(1)}$	0.03	$x_{11(1)}$	0.09
$x_{5(2)}$	0.00	$x_{12(1)}$	0.01
$x_{5(3)}$	0.01	$x_{13(1)}$	0.04
$x_{6(1)}$	0.02	$x_{11(2)}$	0.09

Conclusion: nothing different between treatment and control group (balance).

4. Significance test for A Confounding Variable (Always Use Condom)

   Hypotesis

   H_0: $\tau = 0$ (Confounding variable (always use condom) significant)

   H_1: $\tau \neq 0$ (Confounding variable (always use condom) not significant)

   Significant level:α=10%

   Statistics Test: $W = \dfrac{\hat{\tau}}{Se\left(\hat{\tau}\right)}$

   Decision:Reject H_0becausep-value<α (0,07772< 0.10)

Table 2. Significance Test forAConfounding Variable

Coefficient	Estimation	Standard Error	Wald	*P-value*
Intercept	0.1320	0.0452	2.920	0.00387
x_8	0.2210	0.1247	1.773	0.07772

Based on Table 2, is inject drugs user who always use condom can infected 1.25 times more than not always use condom. Confounding variable (always use condom) not significant.

5. CONCLUSION

The result of our study concluded that:

1. Estimation of propensity score using logistic regression with MLE method shows that the first differentiation of log funstion is not close form. So, Newton Raphson iteration to get the estimation.
2. *Penasun* who always use condom in their sexual activity have the risk 1.25 times higher than penasun who rarely use condom. This result is in contrast to the fact that the lower use of condom, the higer risk to be infected HIV/AIDS. Since

penasun get higer risk of getting infected HIV/AIDS through sharing the same syringe, so it is possible to transfer the virus to their fixed couple or unfixed couple through sexual activities.

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