Random Effect Meta-Analytic Structural Equation Modeling (MASEM) Estimation Using The Method Of Moment: Case Study On The Poverty In The Island Of Java

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Abstract. Meta-Analytic Structural Equation Modeling (MASEM) is divided into two types according to the homogeneity of the effect size, the fixed-effects MASEM, and the random-effects MASEM. The random effects of MASEM are heterogeneous or there are variations in the effects of the study population, thus implying both between-study variance and within-study variance. Accordingly, the process of estimating the MASEM random-effects parameters involves an additional process, the estimation of the variance between studies. The initial process of MASEM parameters was estimated with generalized least squares (GLS) and then estimated the variance between studies. The iterative EM algorithm is used to estimate the variances between studies of random effects MASEM GLS but this method may not achieve convergence. So, a non-iterative procedure was developed to estimate the variance between studies using the moment method. Data on poverty on the island of Java are likely to differ. Poverty data, if collected from a different population in between province, will be more accurate and in line with targets. The poverty model with the economy, human resources, and health as the right exogenous variables on the island of Java. The results of applied random-effect MASEM GLS with the method of moment approach to estimate the variance between studies on a poverty model show that the coefficient of each economic, health, and human resources variable on poverty is 0.4942, -0.1106, and -0.2843. When human resources increase along with health, people's creativity and productivity also increase, it affects the decline in the value of economic indicators or is equivalent to the increase in the economy of the community so that poverty decreases.

Keyword: MASEM, Random Effect Model, Method Of Moment, Poverty

1. Introduction

The meta-analysis was first proposed by Glass (1976) which can be defined as a statistical method to integrate the result analysis from previous studies which has similarities [1]. Meta-analysis involves the process of identifying, collecting, reviewing, coding, and interpreting various research studies. The main
goal of the meta-analysis is to find the effect size. Effect size is a measure of the size of the effect, the difference, and the relationship between a variable and other variables [2].

Structural Equation Modeling (SEM) is a multivariate statistical analysis technique. This structural equation modeling is a combination of factor analysis and multiple regression analysis making it possible to analyze the structural relationship between the measured variable and the latent construct [3]. Research using structural equation modeling (SEM) [4–8] can be integrated into the meta-analysis method based on effect size correlation. The combination of SEM and meta-analysis methods is called Meta-Analytic Structural Equation Modeling (MASEM).

The meta-analytic structural equations modeling (MASEM) involves 2 stages of analysis, synthesizes correlation or covariance matrices from several studies or results, then applies SEM techniques to test the fit or explain the relationship between the variables to using a combined correlation or covariance matrix [9]. MASEM is a correlation-based meta-analysis so that the MASEM data type is a correlation matrix of the research studied.

In general, according to the homogeneity of the effect size, the MASEM model is divided into two types, the fixed-effects MASEM and the random-effects MASEM [2, 10]. The fixed-effects model assumes that the effect on the population is homogeneous across studies, while the random-effects model is heterogeneous or that there are variations in the effects of the study population, thus implying between studies variances and within studies variances. Accordingly, the process of estimating random effect MASEM parameters involves an additional process, estimating the variance between studies. This type of search effect size is rarely homogeneous because it is difficult to find studies that give the same results.

The first MASEM estimation model was developed by Becker in 1992 using the generalized least squares (GLS) estimation method. The initial process of the MASEM parameters was estimated with GLS, the next test of homogeneity if the test of homogeneity of the results is heterogeneous then estimated the variance between studies for the random-effects model and the final step is a fitting model [11, 12]. MASEM estimator In addition to the GLS method, there are other methods, namely the TSSEM method [13–15]. However, this method was developed in a different simulation with MASEM GLS which was analyzed analytically.

Random effect MASEM GLS using the iteration of the EM algorithm to estimate the variance between studies. In addition, the estimation variance between studies random effect MASEM has also been developed using the iterative restricted maximum likelihood [16, 17]. However, this method may not achieve convergence. Thus, a non-iterative procedure was developed to estimate the variance between studies using the method of moment. Estimation of the variance between studies random effect MASEM GLS with the moment method gave a better statistical Wald value compared to the iteration of the EM algorithm [18].

The implementation of MASEM on socio-economic issues in Indonesia has been completed, including health status issues in East Java Province [19], and poverty [20, 21]. Poverty data on the island of Java between provinces are likely to differ. Poverty data, if collected from a different population in between province, will be more accurate and in line with targets. The model of poverty with the economy, human resources, and health as exogenous variables is appropriate on the island of Java [22, 23].

In this paper, the novelty random effect MASEM GLS with the method of moment [18] is used to analyze the poverty model in Java. In addition, the results obtained are compared to the analysis of poverty on paper [21]. This research aims to provide the best results of the poverty model so that it can become a policy proposal for the Indonesian government to overcome poverty.

2. Method

2.1. MASEM with GLS approximation

Correlation matrix as many as \( k \) studies and \( p \) predictor variables will exist \( p^* = \frac{p(p+1)}{2} \) the correlation will be estimated. The MASEM model, estimated using the generalized least squares (GLS) method,
has 4 variables. There is a correlation matrix, an identity matrix, a correlation matrix estimator, and an error matrix which is approximated by the variant covariance matrix $\Sigma$. It is supposed to complete the equation: \[18, 21\]

\[
b_{kp}\times 1 = W_{kp}\times kp\times p_{kp} + e_{kp}\times kp
\]  

\[
\Sigma = \begin{bmatrix}
\Sigma_1 & 0 & \cdots & 0 \\
0 & \Sigma_2 & \cdots & 0 \\
\vdots & \ddots & \ddots & \vdots \\
0 & 0 & \cdots & \Sigma_k
\end{bmatrix}
\]

Equation (1) is estimated using the GLS method, the following forms of the estimator are obtained:

- **Fixed Effect Model**
  \[
  \hat{\beta}_F = \left(W^T \Sigma^{-1} W\right)^{-1} W^T \Sigma^{-1} b
  \]  
  \[
  Cov(\hat{\beta}_F) = \left(W^T \Sigma^{-1} W\right)^{-1}
  \]

- **Random Effect Model**
  Random effect model is assumed that
  \[
b = W\beta + \delta + e
  \]
  where $\delta_i (1 \leq i \leq k)$ follows $\delta \sim N(0, T)$
  \[
  \Omega = \begin{bmatrix}
  \Sigma_1 + T & 0 & \cdots & 0 \\
 0 & \Sigma_2 + T & \cdots & 0 \\
\vdots & \ddots & \ddots & \vdots \\
0 & 0 & \cdots & \Sigma_k + T
\end{bmatrix}
\]
  so,
  \[
  \hat{\beta}_R = \left(W^T \Omega^{-1} W\right)^{-1} W^T \Omega^{-1} b
  \]  
  \[
  Cov(\hat{\beta}_R) = \left(W^T \Omega^{-1} W\right)^{-1}
  \]

The heterogeneity test used to test the effect size model type conforms to the following equation [24]:

\[
Q_i = d_i^T M_i d_i
\]

with $d$ are defined by $M_i = \Lambda^{(i)} - \Lambda^{(i)} e e' \Lambda^{(i)} / e' \Lambda^{(i)} e$ and $\Lambda^{(i)} = \Sigma^{-1(i)}$. So that the homogeneity test with the GLS method is defined by:

\[
Q = b^T \left[\Sigma^{-1} - \Sigma^{-1} W \left(W^T \Sigma^{-1} W\right)^{-1} W^T \Sigma^{-1}\right] b
\]

test statistics:
- If $Q < \chi^2_{(k-1)p}$, then the Fixed Effect Model or
- If $Q > \chi^2_{(k-1)p}$, then the Random Effect Model.

The second step of this method is a fitting model. Estimating coefficient and the suitability of the model based on [21], pooled correlation matrix $R$ is partitioned into: (assuming consist of 4 variables)

\[
R = \begin{bmatrix}
1 & \beta_1 & \beta_2 & \beta_3 \\
\beta_1 & 1 & \beta_4 & \beta_5 \\
\beta_2 & \beta_4 & 1 & \beta_6 \\
\beta_3 & \beta_5 & \beta_6 & 1
\end{bmatrix} = \begin{bmatrix}
1 & R_{10} \\
R_{01} & R_{11}
\end{bmatrix}
\]

where
The value of the estimated Coefficients latent variable is defined as follow:

\[ R_{11} = \begin{bmatrix} 1 & \beta_4 & \beta_5 \\ \beta_4 & 1 & \beta_6 \\ \beta_5 & \beta_6 & 1 \end{bmatrix}, R_{01} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} \] (12)

then the partial test as follows:

\[ T_{i}^* = \frac{b_i^*}{\sqrt{s_{ii}}} \] (14)

test statistics:
- If \( |T_{i}^*| < Z_{\alpha/2} \) then the effect is not significant
- If \( |T_{i}^*| > Z_{\alpha/2} \) then the effect is significant.

The RSMEA assessment is used to fitting models. According to Cheung [25]

\[ RMSEA = \sqrt{\frac{\max(x^2_{i=0,2} - df)}{N-1} \frac{df}{N}} \] (15)

2.2. Random effect MASEM With Moment Method

The main step of the MASEM random-effects model is to estimate the between-study variance-covariance matrix \( T \). The result of the moments method for the estimate \( T \) based on [18], let

\[ \Psi = Cov(\hat{\beta}_F) = (W^T \Omega^{-1} W)^{-1} = (\sum_{j=1}^{k} \Sigma_j^{-1})^{-1} \] (16)

\[ \Phi = \Psi^{-1} - \sum_{i=1}^{k} \Sigma_i^{-1} \Psi \Sigma_i^{-1} = \sum_{i=1}^{k} \left[ \Sigma_i^{-1} - \Sigma_i^{-1} \left( \sum_{j=1}^{k} \Sigma_j^{-1} \right) \Sigma_i^{-1} \right]^{-1} \] (17)

\[ A = \sum_{j=1}^{k} \Sigma_j^{-1} (b_j - \hat{\beta}_F)(b_j - \hat{\beta}_F)^T - (k - 1)I_{p^* \times p^*} \] (18)

where \( \Sigma_j, b_j, \hat{\beta}_F \) are defined in equation (1)-(4), then

\[ E(A) = \Phi T \] (19)

so the estimator \( T \) with a method of moment is

\[ \hat{T} = \frac{\Phi^{-1} A + A^T \Phi^{-1}}{2} \] (20)

2.3. Research Data Sources and Variables

The main goal of Meta-Analytical Structural Equation Modeling (MASEM) is to summarize various studies on the same topic to come to a conclusion. This is why the poverty model of this study is a slice of research on the factors of poverty on the island of Java that has been conducted. The poverty model is consistent with Figure 1.

Indicators of each latent variable are according to previous studies [21]. In addition, this research data is secondary data from the results of the Statistics Indonesia (SUSENAS) survey in 2017.

3. Result and Discussion

3.1. Random Effect MASEM Algorithm With Method Of Moment

The first step of MASEM analysis is to synthesize a correlation matrix which is a process of meta-analysis method. At this point, there is a test of homogeneity of the effect size model, and the results of the MASEM parameter estimation will be obtained. So, there is a difference of steps between the random
effect MASEM GLS with the iteration of the EM algorithm and the method of moment, namely how to obtain the variance matrix between the studies.

\[
\hat{\theta} = \frac{S_{\theta y}}{k-1} - \left(\frac{1}{k}\right)\sum_{i=1}^{k} \hat{\theta}_{i\theta y},
\]

with \(\hat{\theta}_{i\theta y}\) is a matrix element \(\Sigma_{i}\) like Equation (2) and \(S_{\theta y} = \sum_{i=1}^{k} (b_{i\theta} - \bar{b}_{\theta})(b_{i\gamma} - \bar{b}_{\gamma}) = b' \Sigma \bar{b}_{\gamma} \Sigma_{\theta y} = \sum_{i=1}^{k} b_{i\theta} / k\) and matrix \(B\) is defined as follows [11, 12]:

\[
B = \begin{bmatrix}
\frac{k - 1}{k} & -\frac{1}{k} & \cdots & -\frac{1}{k} \\
-\frac{1}{k} & \frac{k - 1}{k} & \cdots & -\frac{1}{k} \\
\vdots & \vdots & \ddots & \vdots \\
-\frac{1}{k} & -\frac{1}{k} & \cdots & \frac{k - 1}{k}
\end{bmatrix}
\]

while a variance matrix of MASEM GLS with the moment method conforms to equations (16) - (20).

The second step of MASEM consists of fitting the model and at this stage, there is no difference of steps between the MASEM GLS with the EM algorithm and the method of moment. Therefore, the random effect MASEM GLS step or algorithm with the method of moment approach on the variance between studies can be summarized as follows:

**Step Or Algorithm:** Random effect MASEM GLS with a method of moment

1. Collect the correlation matrices for each study

\[
b = \begin{bmatrix}
b_1 \\
b_2 \\
\vdots \\
b_k
\end{bmatrix}
\]

with

Figure 1. Java Island Poverty Model
\[ b_i = \begin{bmatrix} b_{i1} \\ b_{i2} \\ \vdots \\ b_{ip} \end{bmatrix} \]

2: Construct a variant matrix \( \Sigma_{kp' \times kp'} \) is defined as follows:

\[ \sigma_{ia} = \text{Var}(r_{ia}) = \frac{(1 - \rho_{ia})^2}{n_i} \]

\[ \sigma_{ia} = \text{Cov}(b_{ia}, b_{iy}) \]

\[ \text{Cov}(b_{ist}, b_{iuv}) = [0.5 \rho_{ist}\rho_{iuv}(\rho_{isu}^2 + \rho_{itv}^2 + \rho_{itu}^2 + \rho_{ivu}^2) + \rho_{isu}\rho_{ltnu} + \rho_{ltnu}\rho_{ltnu} - (\rho_{ist}\rho_{ltnu} + \rho_{ltnu}\rho_{ltnu} + \rho_{ltnu}\rho_{ltnu} + \rho_{ltnu}\rho_{ltnu})]/n_i \]

3: Homogeneity test effect size model using Equation (10)

4: Arrange a variance matrix of the random effect model

\[ \Omega = \begin{bmatrix} \Sigma_1 + T & 0 & \cdots & 0 \\ 0 & \Sigma_2 + T & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \Sigma_k + T \end{bmatrix} \]

with Equation (16)-(20)

5: Calculates the estimate of the MASEM parameter

1. Fixed effect Equation (3) and (4)
2. Random Effect Equation (7) and (8)

6: Arrange correlation matrix \( R \) corresponds to equation (11) of the element

\[ \hat{\beta} = \begin{bmatrix} \hat{\beta}_1 \\ \hat{\beta}_2 \\ \vdots \\ \hat{\beta}_{kp'} \end{bmatrix} \]

7: Calculates of the coefficient between the latent variables according to equation (13) and the statistical test of equation (14)

8: The fit of the model with the value Root Mean Square Error Approximation (RMSEA) according to equation (15).

**Table 1. Result of Random Effect MASEM With Moments Method**

| Result Of Random Effect MASEM With Moments Method |
|---------------------------------------------------|
| Coefficient Beta | Coeff. Economy → Poverty \((b_{11})\) | 0.4942 |
|                  | Coeff. Health → Poverty \((b_{12})\)  | -0.1106 |
|                  | Coeff. HR → Poverty \((b_{13})\)      | -0.2843 |
| Significant Test | \(|T_{b1}| = |b_{1} / \sqrt{s_{11}}|\)   | 3.7309 (Significant) |
| \(Z_{0.025} = 1.96\) | \(|T_{b2}| = |b_{2} / \sqrt{s_{22}}|\)   | 0.9838 (Not Significant) |
|                  | \(|T_{b3}| = |b_{3} / \sqrt{s_{33}}|\)   | 2.3543 (Significant) |
| Coefficient of Determination | \(R^2\)       | 56.51% |
| Fitting Models    | RMSEA         | 0.000  |

Source: Matlab R2018b Processed Data Output.
3.2. Data analysis and processing

MASEM is a technique for synthesizing a correlation or a covariance matrix and then testing the fit of the model from a combined matrix correlation or covariance with the fitting SEM method. Therefore, in the first step, a correlation matrix of several studies on poverty is needed. In this article, the results of the SEM modeling with the conceptual framework according to Figure 1 in each province become the source of the synthesized research. Based on the research of B. W. Otok, R. E. Standsyah, A. Suharsono, and Purhadi (2019), the correlation matrix can be organized into:

\[
R = \begin{bmatrix}
1 & 0.59 & -0.476 & -0.612 \\
0.59 & 1 & -0.311 & -0.563 \\
-0.476 & -0.311 & 1 & 0.666 \\
-0.612 & -0.563 & 0.666 & 1 \\
1 & 0.591 & -0.495 & 0.326 \\
0.591 & 1 & -0.591 & 0.639 \\
-0.495 & -0.591 & 1 & -0.378 \\
0.326 & 0.639 & -0.378 & 1 \\
1 & 0.827 & -0.604 & -0.753 \\
0.827 & 1 & -0.529 & -0.738 \\
-0.604 & -0.529 & 1 & 0.898 \\
-0.753 & -0.738 & 0.898 & 1 \\
1 & 0.698 & -0.399 & -0.387 \\
0.698 & 1 & -0.747 & -0.251 \\
-0.399 & -0.747 & 1 & 0.231 \\
-0.387 & -0.251 & 0.231 & 1 \\
1 & 0.963 & -0.946 & -0.93 \\
0.963 & 1 & -0.939 & -0.985 \\
-0.946 & -0.939 & 1 & 0.888 \\
-0.93 & -0.985 & 0.888 & 1 \\
1 & 0.829 & -0.848 & -0.447 \\
0.829 & 1 & -0.888 & -0.742 \\
-0.848 & -0.888 & 1 & 0.826 \\
-0.447 & -0.742 & 0.826 & 1
\end{bmatrix}
\]  

The next step is to process the matrix \( R \) equation (21) with the random effects MASEM according to step or algorithm of Random effect MASEM GLS with a method of moment. The author implements this algorithm in the Matlab R2018b software with reference to Becker [11, 12]. The results of the implementation of the Matlab R2018b software show that the results of the homogeneity of \( Q = 425.5881 > (\chi^2_{0.05;30}) \) so that the effect size of this model is a random-effects model. As for the combined correlation matrix is:

\[
R_{\text{proied}} = \begin{bmatrix}
1 & 0.6964 & -0.5995 & -0.5442 \\
0.6964 & 1 & -0.7332 & -0.4262 \\
-0.5995 & -0.7332 & 1 & 0.4453 \\
-0.5442 & -0.4262 & 0.4453 & 1
\end{bmatrix}
\]

and the value of the estimated Coefficients latent variable is shown in Table 1.

3.3. Results Interpretation

The results of the random effect MASEM, where the variance between studies was estimated using the method of moment, showed an RMSEA value of 0.000. The RMSEA value is the same as the fit criteria of the SEM model, which is less than 0.08, so data can be explained well by the model. The interpretation of this MASEM result shows that the economy has a significant effect on poverty at alpha 0.5 with a coefficient of 0.4942, health has no significant effect on poverty at alpha 0.5 with a coefficient of 0.1106 and human resources have a significant effect on poverty at alpha 0.5 with a coefficient of 0.2843.

The economy has a significant positive effect because the economic variable indicator is directly proportional to the poverty variable indicator. If the values of the economic indicators decrease, it means that the economy of the community has increased, then the community has been able to meet its needs independently, which has resulted in a decrease in poverty. This is different from human resources and health which negatively affect poverty. If the HR and Health indicators increase, the HR and Health variables will increase. When human resources increase along with health, people's creativity and...
productivity for their lives will increase, which will improve their standard of living and poverty will decrease.

The comparison of the random effect MASEM GLS which estimates the variance between studies with the method of moment and the EM algorithm shows that the RMSEA value of the approach method of moment is smaller than that of the EM algorithm according to the results of the article [21]. Moreover, based on the value of $R^2$, it also shows that the method of moment (56.51%) is larger than the EM algorithm (50.60%). This explains that the performance and results interpretation of the random effect MASEM GLS with the current method is better.

4. Conclusion
This study can conclude that the economy has a significant positive effect with a coefficient of 0.4942 because the indicators of economic variables are directly proportional to the indicators of poverty variables. However, health and human resources have a negative effect with coefficients of -0.1106 and -0.2843 respectively on poverty. When human resources increase at the same time as people's health, creativity, and productivity increase, it also affects the decline in the value of economic indicators or the same as the increase in the economy of the community. When these 3 variables show an increase, it can lead to a decrease in the poverty rate in Java.

The results of the random effect MASEM application which estimates the variance between studies using the method of moment on the poverty model show better performance and interpretation results compared to the EM algorithm approach. The results of this poverty model may improve on the previous poverty model which used the EM algorithm approach.

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