SELECTION AND MODELING OF SUSTAINABLE DEVELOPMENT INDICTORS: INDONESIAN CASE

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Abstract

The objectives of this study are as follows: (a) to select indicators that could be linked to an operational definition for sustainable development in Indonesia; (b) to assess the accessibility, quality and relevance of the best available data for developing such indicators; (c) to apply modeling techniques for discerning the linkages among indicators; and (d) to provide recommendations to policy makers, and for further indicator selection and modeling research. This paper discusses in detail how to build a model of sustainable development indicators (SDI) by using structural equations with latent variables. The model of SDI, resulted in this study, gives right signals on what has been happening to development in Indonesia. The result of this study can assist policy-makers in identifying appropriate policies and in monitoring the effectiveness of policy interventions.

1. Introduction

Agenda 21, the global blueprint for sustainable development called on countries to develop and identify indicators of sustainable development as a basis for decision-making at all level. A large number of scientists have expended considerable effort to define sustainable development and select sustainable development indicators (SDI). They hope that collection and monitoring of such indicators will provide important policy guidance to decision-makers and provide a means for tracking sustainable development (Kammerbauer at al., 2001; Cornelissen at al., 2001; Veleva at al., 2001; Hanley at al., 1999; Cole at al., 1998; Friend, 1996). While many studies have provided a more critical basis for selecting indicators, most policy-makers continue to be frustrated by the lack of tangible progress in identifying useable indicators that are easy to understand, inexpensive to measure and supported by a political consensus.

Gustavson et al (1999) suggested that it would be more fruitful and cost-effective to focus attention on a small number of indicators within selected indicator classes (such as economic, social, environmental or human health indicators. Their work in the Fraser River Basin, for example, found that many indicators were closely correlated (and hence substitutable) and that a proliferation of indicators did not necessarily improve the reliability of models to provide informed policy guidance. Furthermore, the work showed that data at the smaller ecosystem level were not reliable, and models of large-scale systems are more readily linked together because they can rely on commensurable data. Many of the data that were available at the small ecosystem level were non-commensurable and could not be used reliably in statistical analyses.

This research is designed with the following objectives:

a) To select indicators that could be linked to an operational definition for sustainable development in Indonesia;
b) To assess the accessibility, quality and relevance of the best available data for developing such indicators;
c) To apply modeling techniques for discerning the linkages among indicators; and
d) To provide recommendations to policy makers, and for further indicator selection and modeling research.

2. Structural Equation Model With Latent Variables

Structural equations with latent variables can be used to describe the linkages among sustainable development indicators. Latent variables are *unobserved* or *unmeasured variables* (factors) that represent unidimensional concepts in their purest form. The observed variables (indicators) of a latent variable contain random or systematic measurement errors, but the latent variable is free of these. Since all latent variables correspond to concepts, they are hypothetical variables. Concepts and latent variables, however, vary in their degree of abstractness (Bollen, 1989).

In this paper, there are three factors (latent variables) that represent performance of sustainable development in Indonesia. These factors are *human resource*, *economy*, and *quality of life*. There, of course, can be many possibility of *causal models* or *pressure-state-response framework* that can be investigated and tested to discern the linkages among indicators. The following hypothetical model in Figure 1 is investigated in this research. This model hypothesizes a relationship among three constructs or concepts, which suggests that the *human resource* (ξ_1) affects the performance of *economy* (η_1), which in turn affects the *quality of life* (η_2). The *quality of life* (η_2) is also directly affected by the *Human resource* (ξ_1).

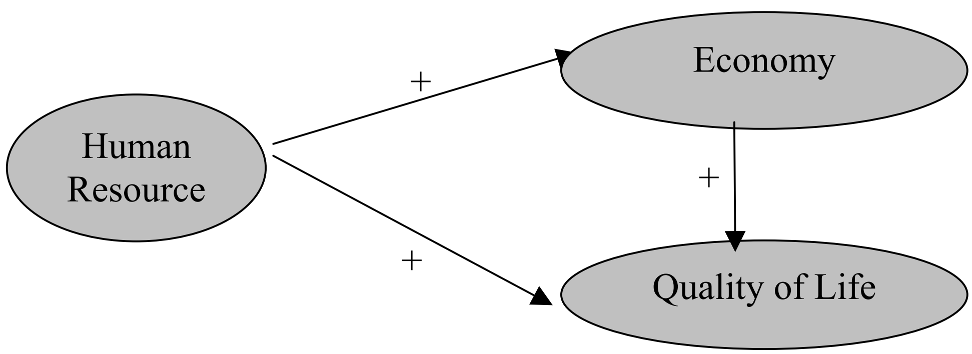

Figure 1. A Model Framework of Sustainable Development in Indonesia

3. Data and Methods

One of key goals of this study is to assess the ability of *existing* information sources to provide sustainable development indicators that are relevant to *projective* modeling. The existing data of indicators, published by ADB, World Bank, and BPS-Bappenas-UNDP are evaluated in this study.

The indicator selection framework adopted is shown in Figure 1, in a form of cause-effect or *pressure-state-response framework*. Indicators are selected for their relevance to the ecological or environmental, economic, social, and Institutional subsystems. For each subsystem, indicators will be classified according to their pressure (driving force), state, and response characteristics. All subsystems and dimensions will also be monitor over time. Indicators that may provide a causal link in such a chain are therefore preferred for indicator modeling.

	DIMENSION		
SUBSYSTEM	Pressure (Driving Force)	State	Response
ECOLOGICAL or ENVIRONMENTAL - Air - Water - Land - …			
ECONOMIC - Production - Consumption - ……			
SOCIAL - Culture - Human Security - …			
INSTITUTIONAL - National Sustainable Strategy - Information Access - …			

Figure 2. Indicator Selection Framework

Since the volume of information is excessive, selection of indicators is conducted based on their validity, reliability, and availability. In addition to the theoretical considerations, the selection of indicator must follow some main criteria, such as: (1) ability to apply meaningfully to the Indonesian development condition; (2) availability of comprehensive annual time series; (3) rationale of the indicator linkage with an appropriate dimension of an issue area; and (4) cost and accessibility of the data.

There are three group of SDI based on their unit of observation. They are: (1) National SDI, (2) SDI by province, and (3) SDI by district (Java & out of Java). The following indicators has been selected and used to build a tentative model of sustainable development in Indonesia, that is:

1. **Unemploy**ment rate,
2. Percent of population living below the **poverty**,
3. **Gini** index of income inequality.
4. **Nutrition**al status of children,
5. **Life exp**ectancy at birth,
6. Percent of household with adequate sewage disposal facilities (**sanitation**),
7. Percent of population with access to primary **health** care **facilities**,
8. Adult **literacy** rate,
9. Per capita **spending**,
10. Number of **education** years (duration),
11. Ratio of female wage to male **wage**,
12. **Mortality** rate under 5 years old,
13. Population with access to safe drinking **water**,
14. Dirt **Floor** Area per person
15. Number of recorded **crime**s per 100,000 population,

16. Population **density**,
17. **GDRP** per capita,
18. **E**conomic **growth**,
19. **Paddy prod**uctivity,
20. **Emission** of CO,
21. **Forest** area as a percent of land area,

Due to the variation of indicators among districts in Indonesia, this paper focuses the analysis on indicators by district (Java and out of Java) and by province in 1999. The sustainable development model given in Figure 1 is referred to as a structural or a path model, which can be tested whether or not data support the hypothesized model.

The model of sustainable development indicators in this study consists of two parts: the measurement model and the structural equation model. The measurement model specifies how latent variables (ξ_1, η_1, and η_2) depend upon or are indicated by the observed variables (SDI by district). It describes the measurement properties (reliabilities and validities) of the observed variables, and is defined by the following matrix equations:

$$\begin{pmatrix} x_1 \\ \vdots \\ x_q \end{pmatrix} = \begin{pmatrix} \lambda_{11}^x \\ \vdots \\ \lambda_{q1}^x \end{pmatrix} \xi_1 + \begin{pmatrix} \delta_1 \\ \vdots \\ \delta_q \end{pmatrix} \quad \text{or}$$

$$\mathbf{x} = \Lambda_{\mathbf{x}}\xi + \delta \tag{1a}$$

and

$$\begin{pmatrix} y_1 \\ \vdots \\ y_t \\ y_{t+1} \\ \vdots \\ y_p \end{pmatrix} = \begin{pmatrix} \lambda_{11}^y & 0 \\ \vdots & 0 \\ \lambda_{t1}^y & 0 \\ 0 & \lambda_{(t+1)2}^y \\ 0 & \vdots \\ 0 & \lambda_{p2}^y \end{pmatrix} \begin{pmatrix} \eta_1 \\ \eta_2 \end{pmatrix} + \begin{pmatrix} \in_1 \\ \vdots \\ \in_t \\ \in_{t+1} \\ \vdots \\ \in_p \end{pmatrix} \quad \text{or}$$

$$\mathbf{y} = \Lambda_{\mathbf{y}}\eta + \in \tag{1b}$$

where : **y** is a p x 1 vector of observed response or outcome variables.
- **x** is a q x 1 vector of predictors or input variables.
- η is an m x 1 random vector of latent dependent (endogenous) variables
- ξ is an n x 1 random vector of latent independent (exogenous) variables
- $\Lambda_{\mathbf{y}}$ is a p x m matrix of coefficients of the regression (*loading*) of **y** on η.
- $\Lambda_{\mathbf{x}}$ is a q x n matrix of coefficients of the regression (*loading*) of **x** on ξ.
- $\in$ is a p x 1 vector of measurement errors in **y**.
- δ is a q x 1 vector of measurement errors in **x**.

The second part of SDI model is the structural equation model, which specifies the causal relationships among the latent variables, and assigns the explained and unexplained variance. It is defined by the following matrix equation:

$$\begin{pmatrix}\eta_1\\ \eta_2\end{pmatrix} = \begin{pmatrix}\gamma_1\\ \gamma_2\end{pmatrix}\xi_1 + \begin{pmatrix}0 & 0\\ \beta_{21} & 0\end{pmatrix}\begin{pmatrix}\eta_1\\ \eta_2\end{pmatrix} + \begin{pmatrix}\zeta_1\\ \zeta_2\end{pmatrix} \quad \text{or}$$

$$\boldsymbol{\eta = \Gamma\xi + B\eta + \zeta} \qquad (2)$$

where: Γ is an m x n matrix of coefficients of the ξ-variables

B is an m x m matrix of coefficients of the η-variables. **B** has zeros in the diagonal, and (**I – B**) is required to be non-singular.

ζ is an m x 1 vector of equation errors (random disturbances) in the structural relationship between η and ξ.

The computer software of LISREL (LInear Structural RELationships), developed by Jöreskog and Sörbom (1996), can be used to specify, fit, and evaluate structural equation models. The LISREL method can accommodate models that include latent variables, measurement errors in both dependent and independent variables, reciprocal causation, simultaneity, and interdependence.

There are three main steps to build SDI model, i.e.:

(i) Specifying the model based on a theoretical framework.
(ii) Assessing the overall model fit. If the model fit is adequate and acceptable, then we can proceed the next step. Otherwise, we should respecify the model (step i).
(iii) Evaluating and interpreting the estimated model parameters. Given that the parameter estimates are statistically significant, the next question is: to what extent the variables good or reliable indicators of the concepts they purport to measure? If not valid and reliable, go back to step (i)

4. Results and Discussion

After trying many models of SDI, the best SDI model for the districts in Java Island is presented in Figure 3. The diagram shows that there are three indicators of the *'human resource'* latent variable, i.e.: adult literacy rate, education, and unemployment rate. The positive coefficient shows that the higher the adult literacy rate (and also education), the better the human resource. The correlation among three indicators is all positive. It means that the

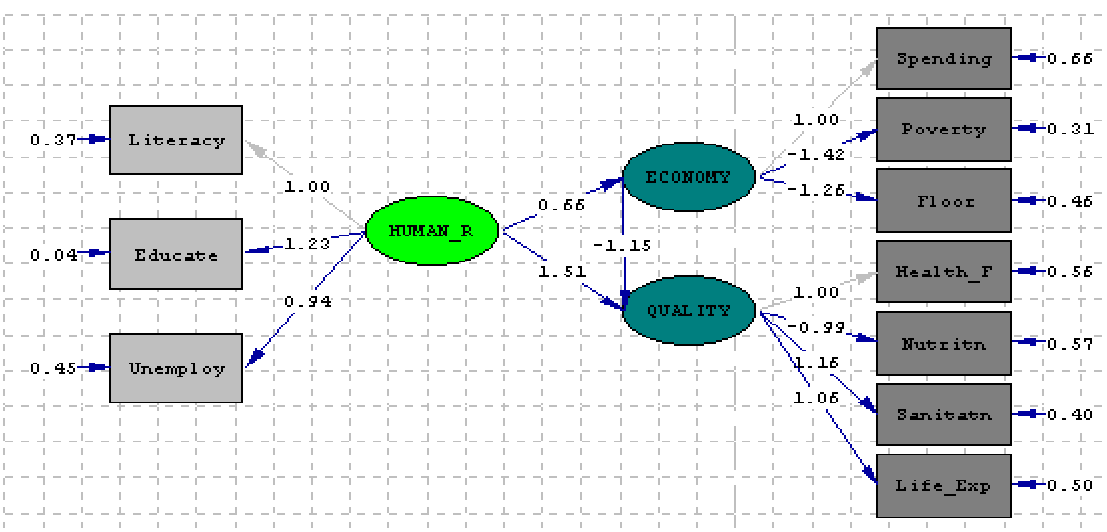

Figure 3. Path Diagram of SDI Model for Districts in Java

longer the education duration, the higher the unemployment rate. This gives signals that graduates from higher education is harder to find the job that is suitable to their skill or field of study. And it implies that we should investigate or evaluate on the direction of senior high school and study programs in universities. In addition, after economic crisis, many higher educated persons become unemployed. Besides, the concept of working used by Central Board of Statistics, reinforce this phenomena. Working means worked at least one hour per week or temporarily not working. For higher educated persons, if as family worker or working in very low productivity job, they prefer to be categorized as 'unemployed' or 'job seeker'.

The indicators of the 'economy' latent variable are as follows: spending, poverty, and dirt floor. All coefficients or loading factors make sense because if the economy is better, the poverty rate and the dirt floor area per capita will be lower. The strong correlation between the poverty rate and the dirt floor area per capita indicates that the measurement of poverty can be approached by the observation on physical condition of house.

There are four indicators of the *'quality of life'* latent variable, i.e.: health care facility, sanitation, mulnutrition, and life expectancy at birth. Their coefficients shows that the better quality of life will be indicated by more health care facilities, better sanitation, higher life expectancy, and lower mulnutritional status of children.

The framework of measurement model above is used to fit data, and it results in a structural model as presented in Figure 4. This model consists of one exogenous variable, i.e. *human resource*, and two endogenous variables, i.e. *economy* and *quality of life*. The direct and total effects of *human resource* on the performance of economy and quality of life are positive and significant. It means that human resource development will positively affect the performance of economy and quality of life. It is worth noting that the effect of economy on the quality of live is negative, meaning that the direction of economic policy needs to be reevaluated because it did not result in sustainable development. Some of the source of economic growth resulted from the exploitation of natural resources. This explanation is strengthened by the negative indirect effect of *human resource* via *economy* on *quality of life*, as shown in Table 1.

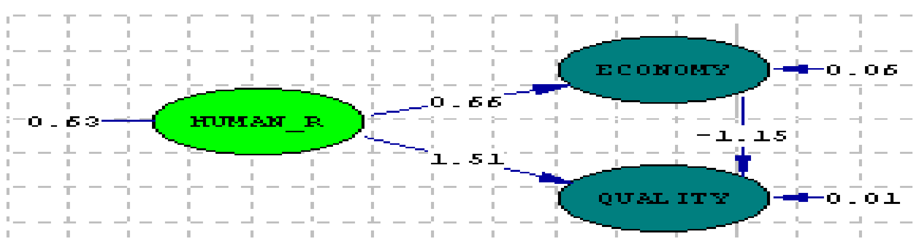

Figure 4. The Structural Model of SDI for Districts in Java

Table 1. Decomposition of total, direct, and indirect effects

Latent Factor	Economy		Quality	
	Effect	*t*-value	Effect	*t*-value
Human_R				
Direct	0.66	5.90	1.51	4.03
Indirect	0.00	0.00	-0.76	-2.28
Total	0.66	5.90	0.75	6.74
Economy				
Direct	--	--	-1.15	-2.30
Indirect	--	--	0.00	0.00
Total	--	--	-1.15	-2.30

After trying many models of SDI, the best SDI model for the districts in out of Java Island is presented in Figure 5. The model performance is not so different, if compared to the SDI model for the districts in Java Island. However, it is worth to note that the indirect effects of *human resource* the direct effect of *economy* on the quality of life are negative, but insignificant. It means that the impact on the quality of life, which in turns on the sustainability of development in out of Java, was not so serious as in Java Island.

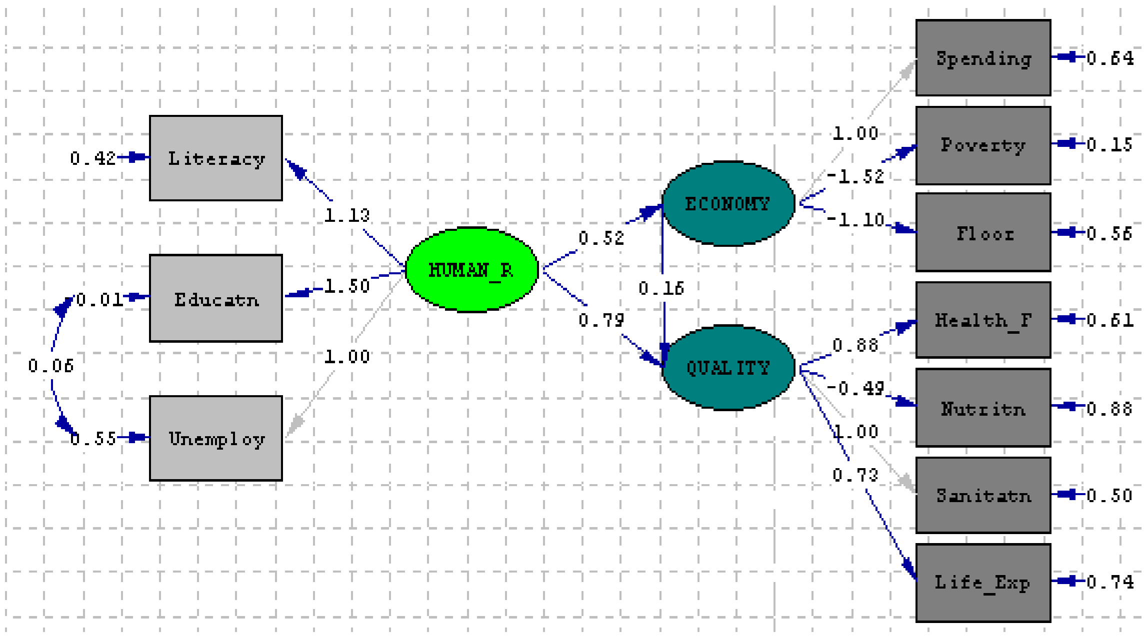

Figure 5. Path Diagram of SDI Model for Districts in Out of Java

Table 2. Decomposition of total, direct, and indirect effects

Latent Factor	Economy		Quality	
	Effect	*t*-value	Effect	*t*-value
Human_R				
Direct	0.52	5.13	0.79	5.57
Indirect	0.00	0.00	0.08	1.46
Total	0.52	5.13	0.87	6.70
Economy				
Direct	--	--	0.16	1.45
Indirect	--	--	0.00	0.00
Total	--	--	0.16	1.45

Data on SDI by province consist of more indicators than those by district because SDI by province has SDI related to gender equality, crime, environmental, etc. If the measurement model is specified based on pressure-state-response framework published by Commission on Sustainable Development. The measurement model in Figure 6 is estimated by LISREL method.

The interpretation of the model is similar to what has been discussed above. It is worth noting that the negative coefficient of Gini index and Forest area on the '*state*' latent variable, indicates that development in Indonesia has directed to the condition of income inequality and decrease in forest area, which in turn will not result in sustainable development.

5. Conclussions

The model of sustainable development indicator, resulted in this study, gives right signals on what has been happening to development in Indonesia. The result of this study can assist policy-makers in identifying appropriate policies and in monitoring the effectiveness of policy interventions.

6. References

Bollen, K.A. 1989. *Structural Equations with Latent Variables*. John Wiley & Sons, New York

BPS-Bappenas-UNDP. 2001. Towards a new consensus: democracy and human development in Indonesia. *Indonesia Human Development Report 2001.* Indonesia; BPS-Bappenas-UNDP..

Cole, D.C., Eyles, J., and B.L. Gibson. 1998. Indicators of Human health in ecosystems: what do we measure? *The Science of the Total Environment.* 224 (1998), pp.201-213.

Cornelissen, A.M.G., van den Berg, J., Koops, W.J., Grossman, M., and H.M.J. Udo. 2001. Assesment of the contribution of sustainability indicators to sustainable development: a novel approach using fuzzy set theory. *Agriculture, Ecosystem and Environment.* 86 (2001), pp.173-185.

Friend, A.M. 1996. Sustainable Development Indicators: Exploring the objective function. *Chemosphere.* Vol.33, No.9, pp.1865-1887.

Gustavson, K.R., Lonergan, S.C., and H.J. Ruitenbeek. 1999. Selection and modeling of sustainable development indicators: a case study of the Fraser River Basin, British Colombia. *Ecological Economics.* 28 (1999), pp.117-132.

Hanley, N., Moffatt, I., Faichney, R., and M. Wilson. 1999. Measuring sustainability: A time series of alternative indicators for Scotland. *Ecological Economics.* 28 (1999), pp.55-73.

Jöreskog, K.G. dan D. Sörbom**.** 1996. *LISREL 8: User's Reference Guide*. Scientific Software International, Inc., Chicago

Kammerbauer, J., Cordoba, B., Escolan, R., Flores, S., Ramirez, V., and J. Zeledon. 2001. Identification of development indicators in tropical mountainous regions and some implications for natural resource policy designs: an integrated community case study. *Ecological Economics.* 36 (2001), pp.45-60.

Levett, R. 1998. Sustainability indicators – integrating quality of life and environmental protection. *Journal of the Royal Statistical Society: Series A*. **Vol. 161** (3). pp.291-302.

Johnson, R.A., and D.W. Wichern. 1998. *Applied Mutivariate Statistical Analysis*. London; Prentice-Hall Int'l, Inc.

Veleva, V., Hart, M., Greiner, T., and C. Crumbley. 2001. Indicators of sustainable production. *Journal of Cleaner Production.* 9 (2001), pp.447-452.

World Bank. 2000. *World Development Indicators*. Washington, WB.

World Bank. 2001. *Indicators of Sustainable Development: Guidelines and Methodologies*. Washington, WB.

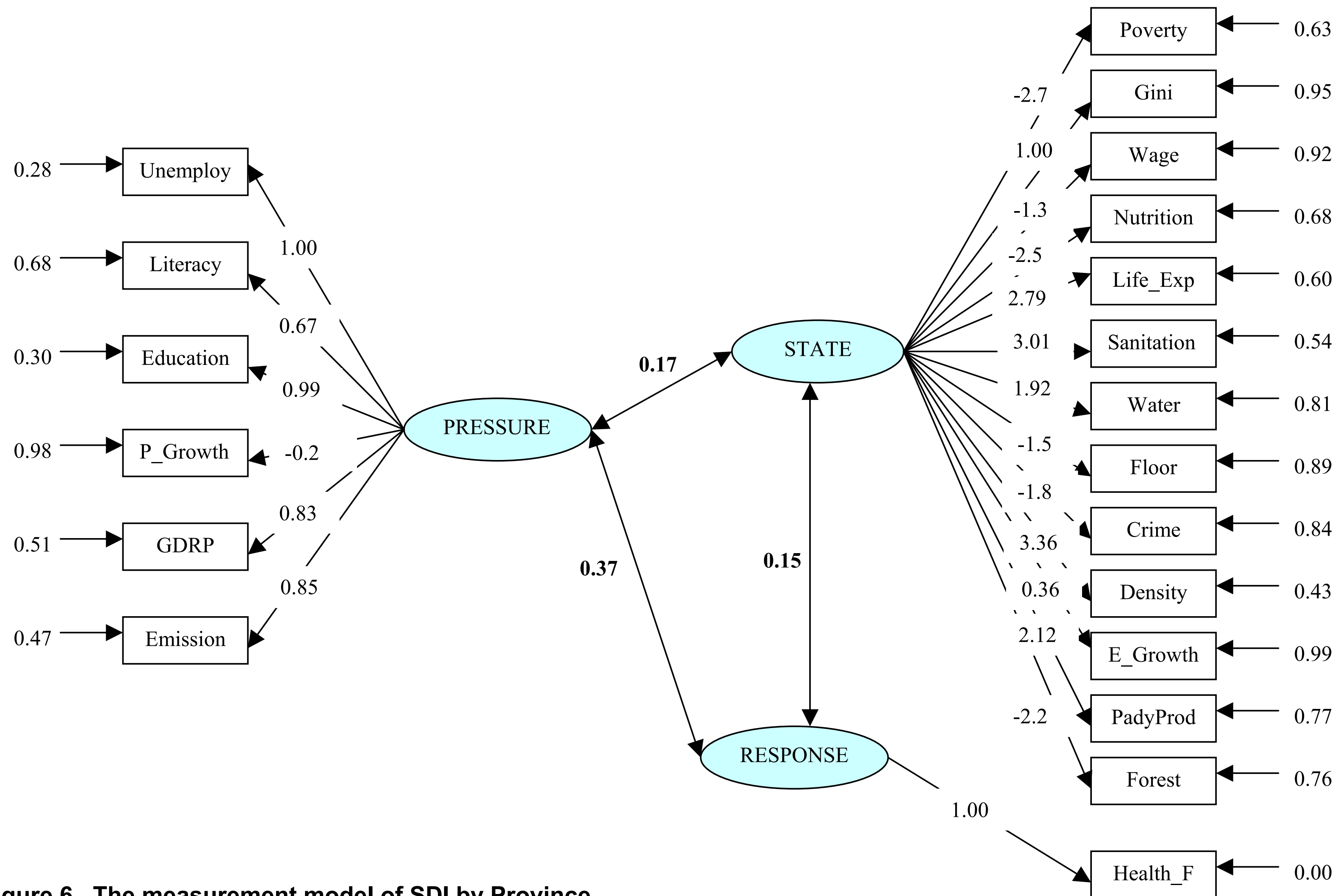

Figure 6. The measurement model of SDI by Province