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Generalized Method of Moment Application in Simultaneous Dynamic Panel Data Equations for Economic Growth, CO₂ Emissions, and Health Expenditures Modelling

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Abstract. Sustainable development is one of the goals of ASEAN as a UN cooperation partner. The high level of CO₂ emissions as one indicator of the decline in environmental quality in several ASEAN member countries, requiring an appropriate policy in order to achieve sustainable development targets. Based on previous research, the relationship between CO₂ emissions, income, and health expenditure is not only simultaneous but also dynamic (changes in a variable spread to the current period and future periods). The relationship between these variables can be described in a system of dynamic simultaneous equations. The ten ASEAN country panel data for eight years (2008-2015) will be used by applying a simultaneous dynamic data panel model. GMM-System Estimator and GMM Arellano-Bond are used to estimate the parameters of dynamic models. Based on the accuracy of the sign with economic theory as well as from the standard error estimator produced, estimates from the GMM-System Estimator are considered better. The resulting estimates indicate a significant simultaneous influence between health expenditure and per capita income and between health expenditure and CO₂ emissions. Per capita income growth affects the growth of CO₂ emissions indirectly through per capita health expenditure. In addition, the lag of each variable, namely per capita income, per capita health expenditure, and CO₂ emission has a positive and significant effect that indicates a long-run multiplier effect.

Keywords: GMM, Simultaneous Equation, Dynamic Panel, CO₂ Emissions

1. Introduction

The development in the macroeconomic sector has several targets, one of the targets is high economic growth. In the future, economic development is expected to be accompanied by sustainable aspects. Sustainable economic development is a development to improve the quality of life of the people without compromising the ability of future generations while maintaining environmental aspects. The need for environmentally friendly development in anticipation of extreme climate change is also in line with one of the objectives of SDG's (Sustainable Development Goals). All countries in the world need to work together to implement sustainable development targets in accordance with the agreement on the 2030 agenda adopted in September 2015 at the UN building. ASEAN (Association of Southeast Asian Nations) as a forum for cooperation in countries in Southeast Asia to collaborate with the United Nations for the achievement of sustainable development targets. This has been stated in the ASEAN 2025 vision that has been aligned with SDG's goals.



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Environment and economic growth are related to each other (Kuznet's environmental curve). The environmental curve theory of Kuznet explains the relationship between degradation of environmental quality and economic growth [1]. Degradation of environmental quality can be assessed from several indicators of environmental pollution, one of which is carbon dioxide (CO₂) emissions. CO₂ emissions are still a big problem both at the world level and in ASEAN countries. Total CO₂ emissions produced in 2016 in Indonesia and Thailand are ranked 13 and 20 respectively from all countries in the world. While per capita CO₂ emissions in Brunei Darussalam and Singapore in the same year amounted to 23.70 and 11.14 tons per capita, far exceeding the per capita CO₂ emissions of the world which was only 4.8 tons per capita [2].

The close relationship between CO₂ emissions and economic growth are not only based on existing economic theory but also from empirical research. The research by [3] and [4] produced a two-way relationship between CO₂ emissions and economic growth. In addition, it also found a long-term relationship between the two variables. High CO₂ emissions result in decreased environmental quality and affect health and will ultimately affect the amount of health expenditure. The relationship between decreasing environmental quality and health expenditure has been empirically proven [5]. On the other hand, optimal health expenditure can improve the quality of public health and labor productivity which will ultimately have an impact on economic growth. [6] and [7] found a two-way relationship between economic growth and health expenditure. Besides the two-way relationship, the dynamic relationship between variables is also interesting to study, so in its development [8] examined the causality and dynamic relationships using Granger tests and co-integration error correction models resulting in health spending and health costs affecting Malaysia's income in the short term. While in the long run, income, health costs, and health expenditures have a two-way relationship.

The close relationship between variables of economic growth, decreasing environmental quality, and health expenditures is interesting to study. The research described above uses a single equation to explain the relationship between variables, and only see the relationship between two of the three related variables. Single equations ignore the interdependence between economic variables, so the need for a system of equations that will be able to better capture the relationships between variables. Existing two-way relationships (simultaneous) between variables can be solved by a simultaneous equation as done by [9]. While long-term and short-term (dynamic) relationships have also been applied to other previous studies including [10], [11], and [12]. From those previous studies, it was developed a method that combines simultaneity and dynamic relationship in a system of equation [13], [14], [15], [16], and [17]. In solving dynamic equations, the GMM-System Estimator and GMM-Arellano Bond methods. The estimator both has an unbiased and consistent nature. In this study, we will see how the performance of the two estimators are from statistical theory and economic theory to illustrate the relationship between economic growth, environmental degradation, and health expenditure in ten ASEAN countries. Therefore, the purpose of this study is to find out the best model from those two estimators.

2. Review Literature

2.1. GMM Arellano-Bond

Arellano-Bond [18] estimated dynamic panel models with GMM by using linear moments and the assumption that there are no serial correlations on errors and the existence of individual effects. In order to eliminate individual effects on dynamic panel data, it is done first-difference [19].

$$(y_{i,t} - y_{i,t-1}) = \delta(y_{i,t-1} - y_{i,t-2}) + (v_{i,t} - v_{i,t-1}); i = 1, 2, \dots, N; t = 1, 2, \dots, T \quad (1)$$

The model of the above equation if written in the form of matrix vectors is as follows:

$$\Delta \mathbf{y}_{i,t} = \delta \Delta \mathbf{y}_{i,t-1} + \Delta \mathbf{v}_{i,t}; i = 1, 2, \dots, N \quad (2)$$

so

$$\Delta \mathbf{v}_{i,t} = \Delta \mathbf{y}_{i,t} - \delta \Delta \mathbf{y}_{i,t-1} \quad (3)$$

In equation (2) it can be seen that $\Delta \mathbf{y}_{i,t-1}$ correlated with $\Delta \mathbf{v}_{i,t}$ so it needs instrumental variable. In the GMM Arellano and Bond method, the order instrument matrix used is the extension of the Anderson and Hsiao instrument matrices, namely:

$$\mathbf{Z}_{dif} = \begin{bmatrix} y_{i,1} & \mathbf{0} & \cdots & \mathbf{0} \\ 0 & [y_{i,1}, y_{i,2}] & \cdots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \mathbf{0} & \cdots & [y_{i,1}, \dots, y_{i,T-2}] \end{bmatrix} = \begin{bmatrix} y_{i,1} & 0 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & y_{i,1} & y_{i,2} & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & y_{i,1} & \cdots & y_{i,T-2} \end{bmatrix}$$

Where $\mathbf{Z}_{dif}$ has ordo size $(T-2) \times \left[\frac{1}{2}(T-2)(T-1)\right]$

Parameter estimates by Arellano and Bond use the GMM principle to get consistent estimates. Estimates GMM for $\hat{\delta}$ is an estimator of (δ) that will minimize $J(\hat{\delta})$.

$$\hat{\delta} = \left[N^{-1} \sum_{i=1}^N \Delta y'_{i,t-1} \mathbf{Z}_i \right] \widehat{\mathbf{W}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta y_{i,t-1} \right]^{-1} \left[N^{-1} \sum_{i=1}^N \Delta y'_{i,t-1} \mathbf{Z}_i \right] \widehat{\mathbf{W}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta y_i \right] \quad (4)$$

Estimator $\hat{\delta}$ is a consistent estimator without depending on the selection of $\widehat{\mathbf{W}}$. The selection of $\widehat{\mathbf{W}}$ will not affect the consistency of estimates, but by choosing an optimal $\widehat{\mathbf{W}}$ will produce efficient estimates. Arellano dan Bond [18] propose optimal weight $\widehat{\mathbf{W}}$ as follows: $\widehat{\mathbf{W}} = \widehat{\mathbf{\Lambda}}^{-1}$ with $\widehat{\mathbf{\Lambda}} = N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta v_i \Delta v'_i \mathbf{Z}_i$

And the estimator will be named as two-step efficient GMM estimator Arellano-Bond:

$$\hat{\delta} = \left[N^{-1} \sum_{i=1}^N \Delta y'_{i,t-1} \mathbf{Z}_i \right] \widehat{\mathbf{\Lambda}}^{-1} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta y_{i,t-1} \right]^{-1} \left[N^{-1} \sum_{i=1}^N \Delta y'_{i,t-1} \mathbf{Z}_i \right] \widehat{\mathbf{\Lambda}}^{-1} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta y_i \right] \quad (5)$$

Exogenous variables in the dynamic model will change the estimator in eq (5) into:

$$\begin{aligned} \left(\begin{matrix} \hat{\delta} \\ \hat{\beta} \end{matrix} \right) &= \left[N^{-1} \sum_{i=1}^N (\Delta y_{i,t-1}, \Delta \mathbf{x}_i)' \mathbf{Z}_i \right] \widehat{\mathbf{\Lambda}}^{-1} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i (\Delta y_{i,t-1}, \Delta \mathbf{x}_i) \right]^{-1} \\ &\quad \left[N^{-1} \sum_{i=1}^N (\Delta y_{i,t-1}, \Delta \mathbf{x}_i)' \mathbf{Z}_i \right] \widehat{\mathbf{\Lambda}}^{-1} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \Delta y_{i,t} \right] \end{aligned} \quad (6)$$

With variance:

$$V \left(\begin{matrix} \hat{\delta} \\ \hat{\beta} \end{matrix} \right) = \left[N^{-1} \sum_{i=1}^N (\Delta y_{i,t-1}, \Delta \mathbf{x}_i)' \mathbf{Z}_i \right] \widehat{\mathbf{\Lambda}}^{-1} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i (\Delta y_{i,t-1}, \Delta \mathbf{x}_i) \right]^{-1} \quad (7)$$

2.2. System GMM

Blundell and Bond [20] propose two estimators which are considered capable of increasing the precision of the first difference GMM estimator. The first estimator proposed is to combine moment level and the first difference in a linear equation. While the second estimator is obtained by estimating the error of the GLS component.

System Model as a combination of first difference model and level model is as follow:

$$\begin{pmatrix} \Delta y_i \\ y_i \end{pmatrix} = \delta \begin{pmatrix} \Delta y_{i-1} \\ y_{i-1} \end{pmatrix} + \begin{pmatrix} \Delta v_i \\ u_i \end{pmatrix}; i = 1, 2, \dots, N \quad (8)$$

So $E(\mathbf{Z}'_{dif} \Delta \mathbf{v}_i) = \mathbf{0}$ and $E(\mathbf{Z}'_{lev} \Delta \mathbf{u}_i) = \mathbf{0}$ for $i = 1, 2, \dots, N$, so $E(\mathbf{Z}'_{sys} q_i) = \mathbf{0}$ for $i = 1, 2, \dots, N$ with $\mathbf{q}_i = \begin{pmatrix} \Delta v_{i,t} \\ u_{i,t} \end{pmatrix}$.

$$E \left(\mathbf{Z}'_{sys} \begin{pmatrix} \Delta v_i \\ u_i \end{pmatrix} \right) = E \left(\mathbf{Z}'_{sys} \left[\begin{pmatrix} \Delta y_{i,t} \\ y_{i,t} \end{pmatrix} - \begin{pmatrix} \Delta y_{i,t-1} \\ y_{i,t-1} \end{pmatrix} \delta \right] \right) = E \left(\mathbf{Z}'_{sys} (\boldsymbol{\theta}_{i,t} - \boldsymbol{\theta}_{i,t-1} \delta) \right) = \mathbf{0} \quad (9)$$

With $\mathbf{u}_i^* = \begin{pmatrix} \Delta v_i \\ u_i \end{pmatrix}$; $\boldsymbol{\theta}_{i,t} = \begin{pmatrix} \Delta y_{i,t} \\ y_{i,t} \end{pmatrix}$; and $\boldsymbol{\theta}_{i,t-1} = \begin{pmatrix} \Delta y_{i,t-1} \\ y_{i,t-1} \end{pmatrix}$

This estimator uses the instrument variable matrix in the form of moment condition level and first difference. The variable instrument in level conditions are as follows:

$$\mathbf{Z}_{level} = \begin{bmatrix} \Delta y_{i,2} & \mathbf{0} & \dots & \mathbf{0} \\ 0 & [\Delta y_{i,2}, \Delta y_{i,3}] & \dots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \mathbf{0} & \dots & [\Delta y_{i,2}, \dots, \Delta y_{i,T-1}] \end{bmatrix} \quad (10)$$

So the instrument matrix in Sys-GMM is a combination of the instrument in level conditions and in the first different:

$$\mathbf{Z}_{sys} = \begin{bmatrix} \mathbf{Z}_{dif} & \mathbf{0} \\ \mathbf{0} & \mathbf{Z}_{level}^p \end{bmatrix} \quad (11)$$

Where $\mathbf{Z}_{level}^p$ is non-redundant subset from $\mathbf{Z}_{level}$.

The principle of parameter estimation using System GMM is to minimize $J(\hat{\delta})$ with weighted $\widehat{\mathbf{W}}$ which a positive definite matrix with size $L \times L$, where $L = \frac{(T+1)(T-2)}{2}$. So

$$\hat{\delta} = \left[N^{-1} \sum_{i=1}^N \boldsymbol{\theta}'_{i-1} \mathbf{Z}_{sys} \right] \widehat{\mathbf{W}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \boldsymbol{\theta}_{i-1} \right]^{-1} \left[N^{-1} \sum_{i=1}^N \boldsymbol{\theta}'_{i-1} \mathbf{Z}_i \right] \widehat{\mathbf{W}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_i \boldsymbol{\theta}_{i-1} \right] \quad (12)$$

The optimal weight $\widehat{\mathbf{W}}$ that has been proposed [20] is as follows: $\widehat{\mathbf{W}} = \boldsymbol{\Psi}^{-1}$ with $\hat{\boldsymbol{\Psi}} = N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \hat{\boldsymbol{\theta}}_{i,t} \hat{\boldsymbol{\theta}}'_{i,t} \mathbf{Z}_{sys}$

And the estimator will be named as two-step efficient System GMM:

$$\hat{\delta} = \left[N^{-1} \sum_{i=1}^N \boldsymbol{\theta}'_{i,t-1} \mathbf{Z}_{sys} \right] \hat{\boldsymbol{\Psi}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \boldsymbol{\theta}_{i,t-1} \right]^{-1} \left[N^{-1} \sum_{i=1}^N \boldsymbol{\theta}'_{i,t-1} \mathbf{Z}_{sys} \right] \hat{\boldsymbol{\Psi}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \boldsymbol{\theta}_{i,t} \right] \quad (13)$$

Exogenous variables in the dynamic model will change the estimator in eq (5) into:

$$\begin{pmatrix} \hat{\delta} \\ \hat{\beta} \end{pmatrix} = \left[N^{-1} \sum_{i=1}^N \begin{pmatrix} \Delta y_{i,t-1} & \Delta x_{i,t-1} \end{pmatrix}' \mathbf{Z}_{sys} \right] \hat{\boldsymbol{\Psi}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \begin{pmatrix} \Delta y_{i,t-1} & \Delta x_{i,t-1} \end{pmatrix} \right]^{-1} \left[N^{-1} \sum_{i=1}^N \begin{pmatrix} \Delta y_{i,t-1} & \Delta x_{i,t-1} \end{pmatrix}' \mathbf{Z}_{sys} \right] \hat{\boldsymbol{\Psi}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \begin{pmatrix} \Delta y_{i,t} \\ \Delta x_{i,t} \end{pmatrix} \right] \quad (14)$$

With variance:

$$V \begin{pmatrix} \hat{\delta} \\ \hat{\beta} \end{pmatrix} = \left[N^{-1} \sum_{i=1}^N \begin{pmatrix} \Delta y_{i,t-1} & \Delta x_{i,t-1} \end{pmatrix}' \mathbf{Z}_{sys} \right] \hat{\boldsymbol{\Psi}} \left[N^{-1} \sum_{i=1}^N \mathbf{Z}'_{sys} \begin{pmatrix} \Delta y_{i,t-1} & \Delta x_{i,t-1} \end{pmatrix} \right]^{-1} \quad (15)$$

2.3. Simultaneous Equation Model

The simultaneous equation model is a model where the dependent variable in an equation can be an independent variable in another equation. The number of equations is the same as the number of variables that are worth explaining. The variables that are valued to be explained are called endogenous variables. Other variables are variables that contribute to explaining the model, this variable is called the predetermined variable. Identification of a simultaneous equation with the order conditions rule gives information on an equation identified correctly (just identified/exactly identified) or overidentified. If $K - k = m - 1$, it is said that the equation is an accurately identified equation (just identified / exactly identified), if $K - k > m - 1$ then it is said that the equation is an overidentified equation. Endogenous variables in simultaneous equations correlate with disturbances, the OLS estimator will produce a biased and inconsistent estimator. Another alternative estimation method is needed, called the Two Stage Least Square method (2 SLS).

3. Methodology and data

The main data sources used are secondary data from the world bank database website and the global carbon atlas website for data on 10 ASEAN countries (Brunei Darussalam, Philippines, Indonesia, Cambodia, Laos, Malaysia, Myanmar, Singapore, Thailand, and Vietnam) from 2008-2015. The

specification of the model built on the Cobb-Douglas production function with several other exogenous variables added, which consists of three models namely the model of economic growth, health expenditure and CO₂ emissions [13]. The three models are used as references in this study. The relationship among those variables can be seen in figure 1.

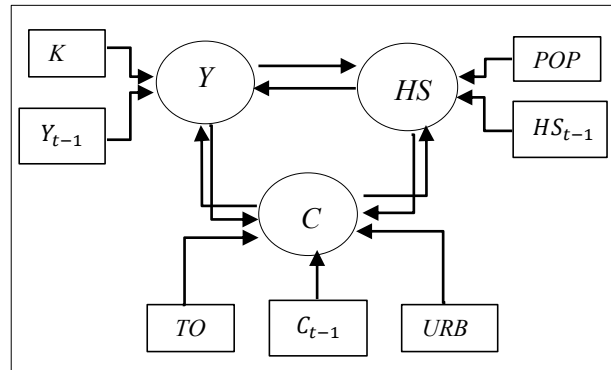


Figure 1. Flow Chart of the Dynamic Simultaneous Model of the Relationship between Economic Growth, CO₂ Emissions, and Health Expenditures.

The flow chart in Figure. 1 can be written in a model as follows:

- (i) $\ln(Y_{it}) = \beta_0 + \beta_1 \ln(Y_{it-1}) + \beta_2 \ln(K_{it}) + \beta_3 \ln(HS_{it}) + \beta_4 \ln(C_{it}) + \varepsilon_{it}$
Hypothesis: $\beta_1, \beta_2, \beta_3 > 0; \beta_4 < 0$
- (ii) $\ln(HS_{it}) = \gamma_0 + \gamma_1 \ln(HS_{it-1}) + \gamma_2 \ln(Y_{it}) + \gamma_3 \ln(C_{it}) + \gamma_4 \ln(POP_{it}) + \varepsilon_{it}$
Hypothesis: $\gamma_1, \gamma_2, \gamma_3, \gamma_4 > 0$
- (iii) $\ln(C_{it}) = \rho_0 + \rho_1 \ln(C_{it-1}) + \rho_2 \ln(Y_{it}) + \rho_3 \ln(HS_{it}) + \rho_4 \ln(URB_{it}) + \rho_5 \ln(TO) + \varepsilon_{it}$
Hypothesis: $\rho_1, \rho_2, \rho_3, \rho_4, \rho_5 > 0$

Y	: GDP per capita	POP	: Percentage of population aging 65+
HS	: Health Expenditure per capita	URB	: Percentage of urban people
C	: CO ₂ Emission per capita	TO	: Ratio of export and import to GDP
K	: Gross Fixed Capital Formation		

To get a dynamic panel simultaneous data equation model, the steps to be taken are as follows:

1. Identify equations using order conditions with the $K - k \geq m - 1$ rule.
2. Check whether there is a simultaneous relationship between equations in the model.
3. Estimate system parameters for simultaneous equations using the 2SLS principle which consists of two stages, namely:
 - a. Look for reduced forms from each structural equation. Then estimate the parameters in the reduced form with GMM Arellano-Bond and GMM-System Estimator. From the results of the first stage of regression, the value of $\hat{Y}_{it}$ it is obtained which has no correlation with the error.
 - b. Next substitute the $\hat{Y}_{it}$ value on $\hat{Y}_{it}$ which is on the right side in each structural equation, followed by estimation parameters with GMM Arellano-Bond and GMM-System Estimator.
4. Test the Arellano-Bond specification (AB Test) and the Sargan Test after the parameters in the simultaneous equation system model are obtained.
5. Formation of estimation models with GMM Arellano-Bond and GMM-System Estimator
6. Evaluation of the goodness of the model and deciding the best model, it will continue to interpret the model and conclusions.

4. Result and Discussion

The model built in this study aims to determine whether there is a relationship between per capita income, per capita health expenditure, and per capita CO₂ emissions in ten ASEAN countries. To work

on a simultaneous equation, it will be preceded by the identification of the order of each equation in the system that was built. The results of the identification of generating orders are overidentified for all three equations in the system. With these results, 2SLS (Two Stage Least Square) can be applied to solve the equation. Hausman test is done first to determine whether there is simultaneity.

Table 1. Simultaneous Testing Summary (Hausman Test)

Structural Equation	Reduce Form(residual)	GMM Arellano-Bond		System GMM	
		P-Value	Conclusion	P-Value	Conclusion
$\ln Y$	$\ln HS$	0.001***	Simultaneous	0.071**	Simultaneous
	$\ln C$	0.025***	Simultaneous	0.894	Bias Simultaneous
$\ln HS$	$\ln Y$	0.001***	Simultaneous	0.118*	Simultaneous
	$\ln C$	0.048***	Simultaneous	0.066**	Simultaneous
$\ln C$	$\ln Y$	0.117*	Simultaneous	0.108*	Simultaneous
	$\ln HS$	0.077**	Simultaneous	0.090**	Simultaneous

This Hausman test will use α of 15% with the results as shown in table 1 which is slightly different between estimates using GMM Arellano-Bond and GMM System. The estimation using GMM Arellano-Bond found a simultaneous relationship between per capita CO₂ emissions and per capita health expenditure with per capita income. Whereas in the estimation using the GMM System it was found that there was only a simultaneous relationship between health expenditure per capita and income per capita. While the simultaneous relationship on CO₂ emissions with per capita income per capita is not significant. As for the results of the other two structural equations, the same conclusion is made, namely per capita income and CO₂ emissions having a simultaneous influence on per capita health expenditure. For the structural equation for CO₂ emissions per capita, we find the results of the simultaneous relationship between per capita income and per capita health expenditure with per capita CO₂ emissions. After testing the relationship of simultaneity, it was followed by the estimation of structural equations with GMM Arellano-Bond and GMM System.

The per capita income structural equation and per capita health expenditure only uses the second lag of endogenous variables as the instrument. Whereas in the structural equation CO₂ per capita emissions only use the third lag of endogenous variables as the instrument. This is because, if all lags are used, the number of instrument variables used will be very large. A large number of instruments compared to N (number of countries) will cause the value of the Sargan test to weaken

From the results in Table 2, the best results will be chosen based on several evaluation criteria of the model, which are a priori economic criteria, statistical criteria, and econometric criteria [21]. In the per capita income equation using the GMM Arellano-Bond estimation and System GMM, the coefficients for each significant predetermined variable are in accordance with the economic rules where all are positive (only for the significant). Whereas for the AB test both m_1 and m_2 for the two estimates are appropriate, which is to reject H_0 in m_1 and fail to reject H_0 in m_2 . As for the exogenous test results of the instruments used, two tests were used, namely the Hansen Test and Test. The Hansen test appears when two-step estimation is used and is more suitable for panel data with fewer countries number. Therefore, the estimation of using GMM Arellano-Bond has met but has not been fulfilled in the GMM System.

For the health expenditure structural equation using the Arellano-Bond GMM estimation, the health expenditure lag coefficient is negative. This will be difficult to interpret for short-run and long-run coefficients. In addition, the sign on the coefficient of CO₂ emissions is also negative and significant. This is contrary to the economic concept where CO₂ emissions should be positively related to health expenditure. Slightly different results are generated in estimates using the GMM System. For significant coefficients, the resulting mark is in accordance with economic rules, as well as the assumption that the AB Test is appropriate. The Sargan test also failed to reject H_0 so that it was appropriate. In the structural equation CO₂ emissions generated by the Arellano-Bond estimation have a negative sign on a significant coefficient which is on per capita income (supposed to be positive). The assumptions on the AB test also cannot be fulfilled by failing to reject H_0 on m_1 and m_2 . While the Sargan and Hansen tests resulted

in failing to reject H_0 in both tests. Whereas in the System GMM estimation results, the results obtained are in accordance with the theory for all significant variable coefficients. The m_1 and m_2 tests are also in accordance with the assumption, which is to reject H_0 in m_1 and fail to reject H_0 in m_2 . For the Sargan test it turned out that H_0 still refused, but the Hansen test was satisfactory, which failed to reject H_0 .

Table 2. Estimation Result on Structural Equation using GMM Arellano-Bond and System GMM

	GMM Arellano-Bond			System GMM		
	Estimated Coefficients	Standard Error	P-Value	Estimated Coefficients	Standard Error	P-Value
1. $\ln Y$						
$\ln Y_{t-1}$	0.765	0.086	0.000***	0.950	0.022	0.000***
$\ln C$	0.084	0.023	0.005***	-0.007	0.006	0.205
$\ln HS$	0.059	0.020	0.015***	0.043	0.018	0.020***
$\ln K$	0.026	0.034	0.449	0.010	0.004	0.011***
Arellano Bond m_1			0.097**			0.028***
Arellano Bond m_2			0.452			0.864
Sargan Test			0.000***			0.004***
Hansen Test			0.425			
2. $\ln HS$						
$\ln HS_{t-1}$	-0.781	0.306	0.029***	0.736	0.059	0.000***
$\ln Y$	2.578	0.708	0.005***	0.157	0.029	0.000***
$\ln C$	-0.031	0.124	0.808	0.048	0.022	0.048***
$\ln Pop$	1.915	0.874	0.053**	0.036	0.040	0.385
Arellano Bond m_1			0.772			0.233
Arellano Bond m_2			0.551			0.506
Sargan Test			0.031**			0.684
Hansen Test			0.152			0.835
3. $\ln C$						
$\ln C_{t-1}$	1.024	0.475	0.056**	0.775	0.121	0.000***
$\ln Y$	-5.305	2.490	0.059**	0.217	0.180	0.256
$\ln HS$	1.116	0.533	0.063**	0.244	0.114	0.059**
$\ln URB$	6.928	2.354	0.015***	-0.547	0.359	0.158
$\ln TO$	0.664	0.205	0.009***	-0.159	0.119	0.210
Arellano Bond m_1			0.225			0.023***
Arellano Bond m_2			0.258			0.168
Sargan Test			0.870			0.006***
Hansen Test			0.271			0.826

The significance of the coefficients generated in the table above uses a partial test, namely the T-test which is preceded by a simultaneous test using the F test. The test can be applied if the assumption of normality is fulfilled. Therefore, normality test is carried out on the residuals produced in each structural equation. The results of the normality test for the three structural equations in the estimation using GMM Arellano-Bond did not meet the normality assumption. This causes the level of significance produced cannot be applied. While the results of the System GMM estimation fulfilled the normality assumption.

Apart from the aspect of signs in economic theory, it can be seen that from the overall coefficients in the three structural equations, the estimation results from the GMM System produce a smaller standard error value. This shows that the results of the GM System are more efficient. These results are in line with the results from [20]. With the results described above, then according to the best model assessment criteria, the model with the estimated GMM System is chosen as the best model, although there are still violations of assumptions on the structural system of per capita income. However, this

violation can be overcome by the addition of T which will result in a conclusion failing to reject H0 in the Sargan test [4].

Estimated results from the GMM System have been chosen as the best model to describe the relationship of the three endogenous variables in the 2008-2015 data period. For different periods and on the same data a similar model will be tried so that general decision is expected to be obtained and valid for all periods. The model will be applied in two different periods, 2008-2012 and 2011-2015. From these results, both the significance and the sign produced from the coefficients of the independent variables vary from the two periods used. These different results occurred in both estimates (using GMM Arellano-Bond and GMM System). With these results indicate that the sign and significance generated from the two estimators for this data with different periods are not consistent (stable). It can be concluded that the decision to choose the best estimator between the two estimators is an option that is not absolute. But there are things that consistent is the magnitude of the standard error value produced. In the estimation results for models with data from 2008-2012 as well as 2011-2015 data, the coefficients produced from the GMM System mostly have smaller error standards than the GMM Arellano-Bond estimators. It can be concluded that the estimates produced by the GMM System are more efficient than the GMM results of Arellano-Bond.

Table 3. Results of Short-run Multiplier and Long-run Multiplier Calculations on Significant Coefficients in a Dynamic Simultaneous Equation System using System GMM

Endogenous Variable	Exogenous Variable	Short-Run Multiplier β	Long-Run Multiplier $\beta/(1 - \delta)$
$\ln Y$	$\ln HS$	0.043	0.856
$\delta = 0.950$	$\ln K$	0.010	0.199
$\ln HS$	$\ln Y$	0.157	0.593
$\delta = 0.736$	$\ln C$	0.048	0.184
$\ln C$	$\ln HS$	0.244	1.085
$\delta = 0.775$			

Table 3 shows the magnitude of the coefficient using System GMM estimator as the best model. We can see that in the structural equation for per capita income, the lag variable per capita income (Y_{t-1}), per capita health expenditure, and gross fixed capital formation are positive and significantly affect per capita income. The coefficient on the health expenditure variable of 0.04 means that in the short term, an increase in per capita health expenditure of 1 percent will cause an increase in per capita income of 0.04 percent and in the long run it will increase by 0.86 percent. These results are in line with [22] that health spending affects economic growth. While a 1 percent increase in the formation of gross fixed capital, in the short term will cause a 0.01 percent increase in income per capita and 0.20 percent in the long run. This condition will be fulfilled if the condition of the other variable is fixed (*ceteris paribus*). This results are in line with [23].

In the structural equation for health expenditures, significant variables are lags in health expenditure, per capita income, and CO₂ emissions. From the coefficients produced, it can be concluded that an increase of 1 percent of income per capita, in the short term will lead to an increase in health expenditures by 0.31 percent and 0.56 percent in the long run. These results are consistent with [24]. Increasing per capita income has a positive impact on public health through increasing health spending. The significant per capita income coefficient in this equation also shows a significant simultaneous relationship between per capita income and health expenditure. This is in line with the results [25]. While the increase in per capita CO₂ emissions by 1 percent will lead to an increase in health spending by 0.16 percent in the short term and 0.3 percent in the long term. This result is in line with [26].

For the third structural equation, namely CO₂ emissions, the variable that significantly affects is the lag of CO₂ emissions per capita and per capita health expenditure. The increase in per capita health expenditure by 1 percent will cause an increase in CO₂ emissions by 0.24 percent in the short term, and

by 1.08 percent in the long term. The magnitude of this long-term coefficient needs to be warned that increasing health spending will trigger high CO₂ emissions. It caused by the fact that the amount of health expenditure as a result of increased income, so a policy or system change is needed so that income increases are not always identical to the increase in CO₂ emissions.

Based on the estimation results in the whole system, the two-way relationship between per capita income and per capita health expenditure is proven significantly, in line with the results of the study [27]. Although per capita income has a result that does not significantly affect CO₂ emissions, it can be said that per capita income has indirect influence through health expenditure. This is because health spending will increase along with the increase in per capita income which will eventually lead to an increase in CO₂ emissions. So that the income that is strived to be increased will have a negative impact on the environment with the increase of CO₂ emissions.

5. Conclusion and recommendation

Some conclusions that can be drawn from the previous discussion are that based on economic theory criteria and standard errors for each variable coefficient, estimates using the GMM System are better than GMM Arellano-Bond to describe the relationship between per capita income, per capita health expenditure, and per capita CO₂ emissions in ten ASEAN countries in 2008- 2015. The conclusion is not absolute, because estimates with the same data but different periods show results that are inconsistent in signs and significance. In terms of error standards, consistency of results was found where the GMM System estimates were more efficient than GMM Arellano-Bond. From the best model, it can be concluded that the increase in per capita income which triggers an increase in health expenditure so that it can increase CO₂ emissions needs to be anticipated so that it does not worsen which can endanger public health. It can be done by using technology and fuel that are environmentally friendly. With the use of environmentally friendly materials, it is expected to boost the economy without exacerbating levels of CO₂ emissions. In addition, the efficiency of energy use also needs to be implemented so that it can minimize CO₂ emissions and the quality of the environment can be maintained. That is what will later support the achievement of the goals of sustainable development (SDGs) where development does not only aim at high income but also considers the environmental and public health aspects.

For further study, periods and number of countries can be added to increase the free degree and increase the p-value of the Sargan Test and can apply fix effects and random effects to be able to see the characteristics of each country.

References

- [1] Todaro. (2006). *Ekonomi Pembangunan*. Jakarta: Erlangga.
- [2] Atlas, G. C. (2018). Retrieved from <http://www.globalcarbonatlas.org/en/CO2-emissions>
- [3] Saboori, B., & Sulaiman, J. (2013). CO₂ Emissions, Energy Consumption and Economic Growth in Association of Southeast Asian Nations (ASEAN) Countries: A Cointegration Approach. *Energy*, hal. 813-822.
- [4] Shahbaz, M., Hye, Q. M., Tiwari, A. K., & Leitão, N. C. (2013). Economic Growth, Energy Consumption, Financial Development, International Trade and CO₂ Emissions in Indonesia. *Renewable and Sustainable Energy Reviews Vol. 25*, hal. 109–121.
- [5] Qureshi, M. I., Khan, N. U., Rasli, A., & Zaman, K. (2015). The Battle of Health with Environmental Evils of Asian Countries: Promises to Keep. *Environ Sci Pollut Res*, hal. 11708–11715.
- [6] Devlin, N., & Hansen, P. (2001). Health Care Spending and Economic Output: Granger Causality. *Applied Economics Letters*, hal. 561-564.
- [7] Amiri, A., & Ventelou, B. (2012). Granger Causality between Total Expenditure on Health and GDP in OECD: Evidence from the Toda–Yamamoto Approach. *Economics Letters*, hal. 541-544.
- [8] Tang, C. F. (2010). Multivariate Granger Causality and the Dynamic Relationship between Health Spending, Income, and Health Price in Malaysia. *MPRA Paper No. 27298*.

- [9] Cornwell, C., Scmidth, P., & Wyhowski, D. (1992). Simultaneous Equations and Panel Data. *Econometrics*, hal. 151-181.
- [10] Kiviet, J. F., Milan, P., & Poldermans, R. W. (2017). Accuracy and Efficiency of Various GMM Inference Techniques in Dynamic Micro Panel Data Models. *Econometrics*, hal. 1-54.
- [11] Lai, T. L., Small, D. S., & Liu, J. (2008). Statistical Inference in Dynamic Panel Data Models. *Journal of Statistical Planning and Inference*, hal. 2763–2776.
- [12] Youssef, A. H., & Abonazel, M. R. (2017). Alternative GMM Estimators for First-Order Autoregressive Panel Model: An Improving Efficiency Approach. *Communication in Statistics- Simulation and Computation*, hal. 1-19.
- [13] Chaabouni, S., & Saidi, K. (2017). The Dynamic Links between Carbon Dioxide (CO₂) Emissions, Health Spending and GDP Growth: A Case Study for 51 Countries. *Environmental Research*, hal. 137–144.
- [14] Hsiao, C., & Zhou, O. (2015). Statistical Inference for Panel Dynamic Simultaneous Equations Models. *Journal of Econometrics*, hal. 383–396.
- [15] Lubis, K. A. (2013). Penerapan Generalized Method of Moment pada Persamaan Simultan Panel Dinamis untuk Permodelan Pertumbuhan Ekonomi Indonesia. Surabaya: [Tesis], Institut Teknologi Sepuluh November.
- [16] Mitze, T. (2010). Dynamic Simultaneous Equations and Panel Data: Small Sample Properties and Regional Factor Demand Modelling for Policy Analysis. *Panel Data Models, Vol. 4 No. C15*.
- [17] Shina, A. F. (2015). Penerapan Generalized Method of Moment Arellano dan Bond Estimator pada Persamaan Simultan Data Panel Dinamis untuk Permodelan Pertumbuhan Ekonomi Indonesia. Surabaya: [Tesis], Institut Teknologi Sepuluh November.
- [18] Arellano, M., & Bond, S. (1991). Some Test of Specification for Panel Data : Monte Carlo Evidence and an Application to Employment Equations. *The Review of Economic Studies, Vol. 58, No. 2*, hal. 277-297.
- [19] Baltagi, B. H. (2005). *Econometric Analysis of Panel Data*. New York: John Wiley & Sons.
- [20] Blundell, R., & Bond, S. (1997). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Econometrics*, hal. 115-143.
- [21] Setiawan, & Kusri, D. E. (2010). *Ekonometrika*. Yogyakarta: Penerbit ANDI.
- [22] Ghorashi, N., & Rad, A. A. (2017). CO₂ Emissions, Health Expenditures and Economic Growth in Iran: Application of Dynamic Simultaneous Equation Models. *Journal of Community Health Research*, hal. 109-116.
- [23] Narayan, S., Narayan, P., & Mishra, S. (2010). Investigating the Relationship between Health and Economic Growth: Empirical Evidence from a Panel of 5 Asian Countries. *Journal of Asian Economics*, 404-411.
- [24] Wang, K.-M. (2011). Health care expenditure and economic growth: Quantile panel-type analysis. *Economic Modelling*, hal. 1536–1549.
- [25] Amiri, A., & Ventelou, B. (2012). Granger Causality between Total Expenditure on Health and GDP in OECD: Evidence from the Toda–Yamamoto Approach. *Economics Letters*, hal. 541-544.
- [26] Zheng, X., Yu, Y., Zhang, L., & Zhang, Y. (2010). Does Pollution Drive Up Public Health Expenditure? A Panel Unit Root and Cointegration Analysis . diakses dari <http://www.hanqing.ruc.edu.cn/admin/uploadfile/201005/20100520103320946.pdf>
- [27] Erdil, E., & Yetkiner, H. (2014). The Granger-causality Between Health Care Expenditure and Output: a Panel Data Approach. *Applied Economics*, hal. 511-518.