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Causal Modeling of the Effect of Foreign Direct Investment, Industry Growth and Energy Use to Carbon Dioxide Emissions

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ABSTRACT

Application of path analysis for causal modeling has been widely used in many areas of studies, such as in social science, education, biology, medical, sociology, and economics. In this study, path analysis is applied to test a relationship model among variables: Foreign direct investment (FDI), industry growth (IND), energy use (ENR), and carbon dioxide (CO_2) emissions. Aims of this study are to know whether there exist direct effect of FDI to IND, direct effect of FDI and IND to ENR, and direct effect of IND and ENR to CO_2 emissions. Results of analysis show that there is a direct effect of FDI to IND where the effect is determined as 0.3597; parameter estimate is significant and meaningfulness. There is direct effect of FDI and IND to ENR. Effect of FDI to ENR is identified as 0.2736; parameter estimate is not significant, but the value is still meaningfulness. Direct effect of IND to ENR is −0.4975; parameter estimate is very significant. There is a direct effect of IND and ENR to CO_2 emissions. Effect of IND to CO_2 emissions is 0.0557; parameter estimate is not significant, but the value is still meaningfulness. Direct effect of ENR to CO_2 emissions is 0.9597 where parameter estimate is very significant and meaningfulness.

Keywords: Path Analysis, Decomposition of Correlation, Direct Effect, Indirect Effect, Total Effect
JEL Classifications: C51, Q4, Q43

1. INTRODUCTION

Causal modeling or path analysis was introduced by Wright (1921; 1934) as a method to analyze direct and indirect effects of variables (Pedhazur, 1997). It is noted that path analysis is not a method to find the causes, but a method that can be used for testing causal model which have been formulated by a researcher. Therefore, path analysis is a useful method in testing theory rather than in generating model. It is a method of analysis to test a proposed model formulated by researcher. A system of relationships in the path diagram can be established among all the variables under investigation based on the hypotheses or by empirical grounds (Gilmour, 1978). Path analysis is an extension and application of traditional regression analysis, and data is used in standardize form, which requires additional assumptions but in turn provides additional information about the model under consideration. One of these assumptions is that the variables are linearly related in a causal fashion (Wonnacott and Wonnacott, 1990; Gilmour, 1978). In exchange for the assumption of linear, additive, and asymmetric relationships between variables, correlation between any two variables in the system can be decomposed into direct and indirect effects (Pedhazur, 1997; Loether and McTavish, 1980). It is expressed in terms of the links between them which leads through other intervening variables as well as the direct link between them (Gilmour, 1978). There are some approaches to estimate the parameters in path analysis, some use correlation approach (Pedhazur, 1997) and some use standardized multiple regression equation (Loether and McTavish, 1980; Wonnacott and Wonnacott, 1990). Aims of the application of path analysis is to compare a model of direct and indirect effects that are assumed to be in between variables under study (Loether and McTavish, 1980). Path analysis model are generally illustrated by means of one headed-arrow connection among some variables included in the model (Pedhazur, 1997).

Application of path analysis has been used in many areas of studies, for example in social research path analysis is applied to data collected in social survey on community response to traffic noise in Tokyo (Osada et al., 1997), in transportation research (Gilmour, 1978), in business and marketing (Bagozzi, 1980). Causal models in the study of human biology and genetic can be found in some research conducted by Fields et al. (1996), Vogler (1985) and Phillips et al. (1987). The model can be found in the field of education conducted by Sewell et al. (1970) where the research aimed in explaining occupational attainment of Wisconsin high school students. In the field of sociology research, the model also can be found in some study conducted by Duncan (1966).

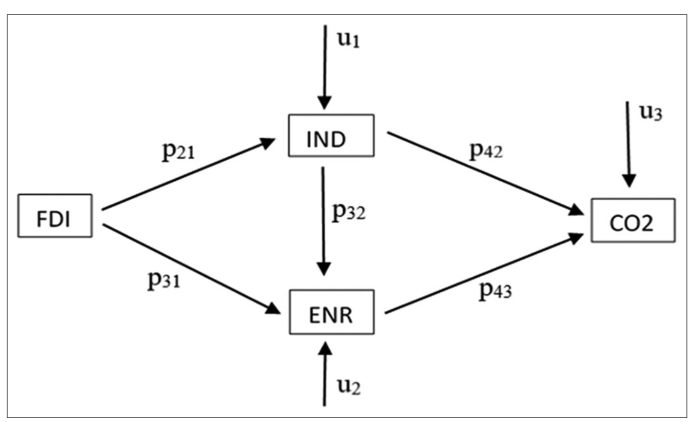
One of the advantages of path analysis or causal modeling is the ability to explain direct effect and indirect effect between variables. Path diagram are useful enough as a simple descriptive tool to describe direct and indirect effects of variables in the model. The coefficient p in the path analysis model is meant to quantify the causal impact on one variable to the other variable as connected by an arrow (Russo, 2009). In path analysis model, is was assumed that all variables used in regression model are in standard form, that is with mean zero and variance one. Therefore, the interpretation of the path coefficients is in standard deviation unit (Loehlin, 2004; Pedhazur, 1997; Wright, 1960); given a numerical value of path coefficient p, say the equation is y = px + u, claims that a unit standard deviation increase in x would in p unit standard deviation increase of y (Engelhardt and Kohler, 2009). Carbon dioxide (CO_2) emissions increased over past few decades (Goodall, 2007). The problem of massive emissions of CO_2 emissions from the energy used, especially fossil fuels, and their impact has become major scientific and political issues (Safaai et al., 2011). The study of CO_2 emissions has been conducted by many scientists all over the world and has become the concerns of many countries. Knapp and Mookerjee (1996) explored the nature of the relationship between global population growth and CO_2 emissions by using Granger causality. The study about the relationship between energy used and CO_2 emissions also have been conducted by many researchers (Lee and Ryu, 1991; Ruth, 1995; Das and Kandpal, 1998, 1999; Noorman and Kamminga, 1998; Sun et al., 2010).

The aims of this study are to explain, (1) are there direct and indirect effects of foreign direct investment (FDI) to industry growth (IND), (2) are there direct and indirect effects of FDI and IND to ENR, and (3) are there direct and indirect effects of IND and energy use (ENR) to CO_2 emissions.

2. STATISTICAL MODELS AND METHOD OF ANALYSIS

Causal model of FDI, IND, ENR, and CO_2 emissions is formulated as follows:

Figure 1: Causal model of the relationship among variables: Foreign direct investment, industry growth, energy use, and carbon dioxide emissions



Based on Figure 1, structural model according to Wonnacott and Wonnacott (1981) can be written as follows:

$$\text{Model 1: } IND = p_{21}\, FDI + p_1 u_1 \quad (1)$$

$$\text{Model 2: } ENR = p_{31}\, FDI + p_{32}\, IND + p_2 u_2 \quad (2)$$

$$\text{Model 3: } CO_2 = p_{42}\, IND + p_{43}\, ENR + p_3 u_3 \quad (3)$$

Where, u_1, u_2, and u_3 are error terms. Based on the models (1), (2), and (3), there are three null hypotheses which will be tested, namely: (1) There is no direct effect of FDI to IND; (2) There are no direct effects of FDI and IND to ENR; and (3) There are no direct effects of IND and ENR to CO_2 emissions. The error terms can be calculated as follows:

$$p_i = \sqrt{1 - RSquares_i}\text{, where i = 1, 2, 3} \quad (4)$$

Furthermore, besides direct and indirect effects, a total effect from one variable to the other variables will also be calculated. Path analysis suggest that the total effect of one variable, say Z_1, on another variable, say Z_0, is defined as the change occurring in Z_0 when Z_1 change one unit of standard deviation, this concept is applied for all the changes in the intervening variables between Z_1 and Z_0. Therefore, total effect is the sum of all paths following the arrows from Z_1 to Z_0 (Russo, 2009).

2.1. Decomposition of Correlations

Advantages of path analysis is considered as a method for decomposing correlation among variables, thereby enhancing the interpretation of correlation. One of the interesting applications of path analysis is the analysis of correlation in its components. Within a given causal model, it is possible to determine the part of a correlation between two variables because of the direct effects and the part which is due to indirect effect (Pedhazur, 1997). Data of FDI, IND, ENR, and CO_2 emissions are transformed into standardized data with mean=0 and standard deviation=1. Therefore, expected values of: E(FDI.FDI)=1, E(IND.IND)=1, E(ENR,ENR)=1, E(CO_2.CO_2)=1, E(FDI.IND)=r_{12}, E(FDI.ENR)=r_{13}, E(IND.ENR)=r_{23}, E(IND.CO_2)=r_{24}, and E(ENR.CO_2)= r_{34}. Where r_{12}, r_{13}, r_{23}, r_{24}, and r_{34} are the correlations between variables: FDI and IND, FDI and ENR, IND and ENR, IND and CO_2, and ENR and CO_2, respectively. From model (1), algebra and tracing rule can be used to find the composition of correlation. Both sides of model (1) is multiplied by FDI and then expected value is taken as presented below.

$$E(IND.FDI) = p_{21}.\ E(FDI.FDI)$$

So that,

$$r_{12} = p_{21} \quad (5)$$

To find composition of correlation r_{13} and r_{23}, from model (2), both sides of model (2) is multiplied by FDI and then expected values are taken such that,

$$E(FDI.ENR) = p_{31}\ E(FDI.FDI) + p_{32}\ E(FDI.ENR)$$

So,

$$r_{13} = p_{31} + p_{32}.r_{12} = p_{31} + p_{32}.p_{21}$$

$$r_{13} = p_{31} + p_{32}.p_{21} \quad (6)$$

Second, both sides of model (2) is multiplied by IND and then expected values are taken such that,

$$E(IND.ENR) = p_{31}\ E(IND.FDI) + p_{32}\ E(IND.IND)$$

So that,

$$r_{23} = p_{31}.r_{12} + p_{32} = p_{31}.p_{21} + p_{32}$$

$$r_{23} = p_{31}.p_{21} + p_{32} \quad (7)$$

To find composition of correlation r_{24} and r_{34}, from model (3), both sides of model (3) is multiplied by IND and then expected values are taken.

$$E(IND.CO_2) = p_{42}\ E(IND.IND) + p_{43}\ E(IND.ENR)$$

So that,

$$r_{24} = p_{42} + p_{43}.r_{23} = p_{42} + p_{43}\ (p_{31}.p_{21} + p_{32})$$

$$r_{24} = p_{42} + p_{43}.p_{31}.p_{21} + p_{43}.p_{32} \quad (8)$$

Second, multiply both sides of model (3) by ENR and then expected values are taken such that,

$$E(ENR.CO_2) = p_{42}\ E(IND.ENR) + p_{43}\ E(ENR.ENR)$$

So,

$$r_{34} = p_{42}.r_{23} + p_{43} = p_{42}\ (p_{31}.p_{21} + p_{32}) + p_{43}$$

$$r_{34} = p_{42}.p_{31}.p_{21} + p_{42}.p_{32} + p_{43} \quad (9)$$

3. RESULTS AND DISCUSSION

Data that used in this study are FDI (World Bank, 2019a), industry (Including infrastructure) annual % growth (IND) (World Bank, 2019b), energy used (kg of oil equivalent per-capita) (ENR) (World Bank, 2019c), CO_2 emissions (metric tons per capita) (World Bank, 2019d). First step before data analysis, data are transformed into standardized form within mean zero and variance one.

From analysis of data for model (1), results are presented in Table 1.

From Table 1, to test null hypothesis whether there is no direct effect of FDI to IND, the F-test = 6.24 with P = 0.0165, therefore the null hypothesis is rejected, there is a direct effect of FDI to IND. R-squares = 0.1294, this means that 12.94% of the variation of IND can be explained by the model. From Table 2, the estimated parameter in model (1) is $p_{21} = 0.3597$. To test partial parameter of model (1) (to test Ho: $p_{21} = 0$), it is calculated that t = 2.50 with P = 0.0165 and the null hypothesis is rejected. The value of $p_{12} = 0.3597 >0.05$ which according to Land (1969) and Heisse (1969) and Pedhazur (1997) is meaningfulness.

Figure 2 indicates positive trend which is in line with the value of estimated parameter, $p_{21} = 0.3597$. Graph shows that if FDI increases, IND also increases. Therefore, according to Land (1969) and Pedhazur (1997), FDI has direct effect to IND. If FDI increases one standard deviation, IND will increase 0.3597 standard deviation. The error is identified as, $p_1 = \sqrt{1-0.1294} = 0.9331$.

Table 1: Analysis of variance for testing model (1)

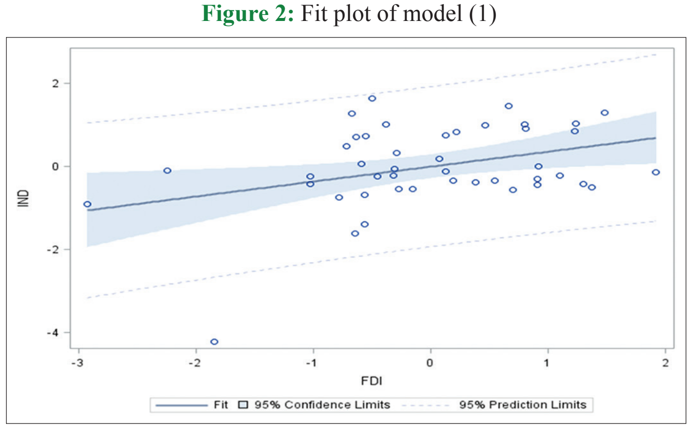
Source	DF	Sum of squares	Mean square	F-value	P-value
Model	1	5.5637	5.5637	6.24	0.0165
Error	42	37.4363	0.8913		
Corrected total	43	43.0000			

R-Squares=0.1294

Table 2: Parameter estimated and testing for partial parameter of model (1)

Variable	DF	Parameter estimate	Standard error	t-value	P-value
Foreign direct investment	1	0.3597	0.1439	2.50	0.0165

Figure 2: Fit plot of model (1)



From analysis of data for model (2), results are presented in Table 3.

From Table 3, to test null hypothesis whether there is no direct effect of FDI and IND to ENR, F-test = 5.93 with P = 0.0055, therefore null hypothesis is rejected, so there are direct effects of FDI and IND to ENR. The R-squares = 0.2245, this means that 22.45% of the variation of ENR can be explained by the model. From Table 4, estimated parameter in model (2) are p_{31} = 0.2736 and p_{23} = −0.4975. For partial test of the parameters through model (2) (to test Ho: p_{31} = 0), it is calculated that t = 1.86 with P = 0.0706 and the null hypothesis is not rejected. The value of p31 = 0.2736 >0.05 which, according to Land (1969), Heisse (1969) and Pedhazur (1997), is still meaningfulness, therefore it is not needed to be deleted from the model. To test Ho: p_{32} = 0, calculation presented that t = −3.38 with P = 0.0016 and the null hypothesis is rejected. Therefore, there are direct effects of FDI and IND to ENR.

Figure 3 presents contour fit plot of model (2) which also indicates positive trend if the value of FDI increases, the value of ENR increases while the other variable is being constant. But there is negative trend if the value of IND increases, the value of ENR decreases (blue area) while the other variables are being constant, Figure 4 also supports this finding.

Analysis of data for model (3) are presented in Table 5.

Testing of null hypothesis whether there are no direct effect of IND and ENR to CO_2 emissions, Table 5 presents result as F-test = 152.54 with P ≤ 0.0001, therefore null hypothesis is rejected, so there are direct effects of IND and ENR to CO_2. R-squares = 0.8815, which means 88.15% of the variation of CO_2 emissions can be explained by the model. From Table 6, the estimated parameters in model (3)

Table 3: Analysis of variance for testing model (2)

Source	DF	Sum of squares	Mean square	F-value	P-value
Model	2	9.6528	4.8264	5.93	0.0055
Error	42	33.3472	0.8133		
Corrected total	43	43.0000			

R-Squares=0.2245

Table 4: Parameter estimated and testing for partial parameter of model (2)

Variable	DF	Parameter estimate	Standard error	t-value	P-value
Foreign direct investment	1	0.2736	0.1474	1.86	0.0706
Industry growth	1	−0.4975	0.1474	−3.38	0.0016

Table 5: Analysis of variance for testing model (3)

Source	DF	Sum of squares	Mean square	F-value	P-value
Model	2	37.9057	18.9528	152.54	<0.0001
Error	42	5.0943	0.1242		
Corrected total	43	43.0000			

R-squares=0.8815

are p_{42} = 0.0557 and p_{43} = −0.9597. To conduct partial test of the parameters in model (3), to test Ho: p_{42} = 0, it is determined as t = 0.95 and P = 0.3347, so the null hypothesis is not rejected. But the value of p_{42} = 0.0557 >0.05 which, according to Land (1969), Heisse (1969) and Pedhazur (1997), is still meaningfulness, therefore it is not needed to be deleted from the model. To test Ho: p_{43} = 0, it is determined that t = 16.377 with P = 0.0001 and the null hypothesis is rejected. Therefore, there are direct effects of IND and ENR to CO_2 emissions.

According to Figure 5, contour fit plot of model (3) also indicates positive trend if the value of ENR increases, the value of CO_2 emissions increase (move to red area, high response for CO_2 emissions), while the other variable is being constant. But there is negative trend as if the value of IND increases, the value of CO_2 emissions decreases while the other variable is being constant. Based on Table 7, correlation coefficients of FDI and ENR (r_{13}), IND and ENR (r_{23}), IND and CO_2 (r_{24}), and ENR and CO_2 (r_{34}) are equal to the results of decompositions of correlation using path analysis as given in the Table 8-11.

3.1. Direct, Indirect, and Total Effects and Decomposition of Correlation

Correlation between variables and estimation of causal model are given below:

Figure 3: The contour fit plot of model (2)

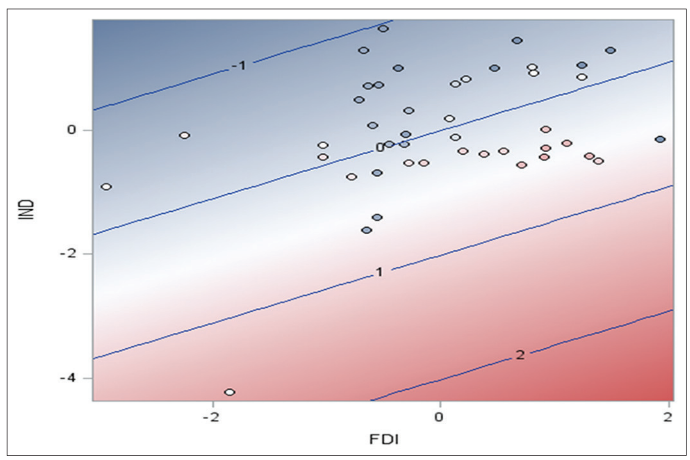
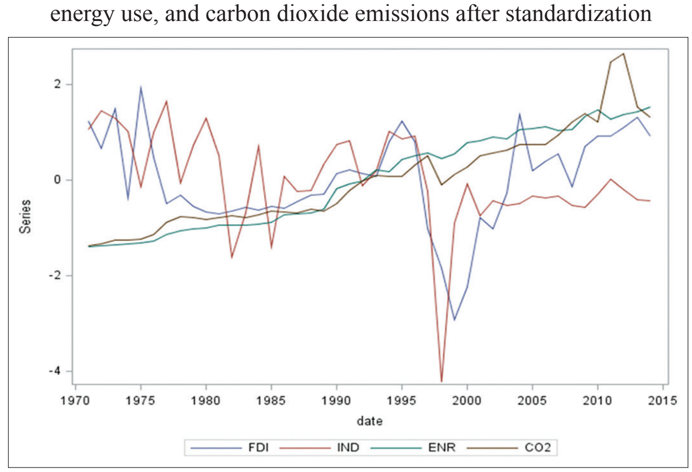


Figure 4: Plot of data foreign direct investment, industry growth, energy use, and carbon dioxide emissions after standardization



From the analysis, it is found that the estimated model (1) is

$$IND = 0.3597\ FDI \quad (10)$$

Where unexplained variation is $p_1 = \sqrt{1-0.1294} = 0.9331$.

Direct effect of FDI to IND is p_{21} = 0.3597, this means that for everyone if standard deviation increases in FDI, IND will increase by 0.3597 standard deviation.

Estimated model (2) is presented in Equation (11).

$$ENR = 0.2736\ FDI – 0.4975\ IND \quad (11)$$

Where unexplained variation is $p_2 = \sqrt{1-0.2245} = 0.8806$.

Figure 5: The contour fit plot of model (3)

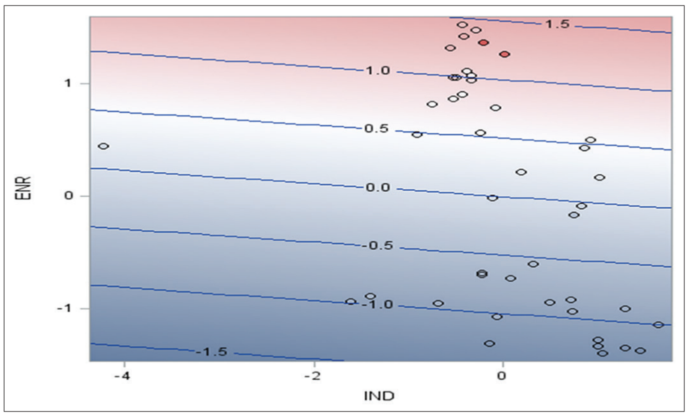


Table 6: Parameter estimate and testing for partial parameter of model (3)

Variable	DF	Parameter estimate	Standard error	t-value	P-value
Industry growth	1	0.0557	0.0586	0.95	0.3474
Energy use	1	0.9597	0.0586	16.37	<0.0001

Table 7: Pearson correlation coefficients, n=44, Probability >|r|under Ho: Rho=0

	FDI	IND	ENR	CO_2
FDI	1.0000	0.2814 (0.0642)	0.0162 (0.9169)	0.1183 (0.4443)
IND		1.0000	−0.3991 (0.0073)	−0.3273 (0.0301)
ENR			1.0000	0.9375 (<0.0001)
CO_2				1.0000

FDI: Foreign direct investment, IND: Industry growth, ENR: Energy use, CO_2: Carbon dioxide

Table 8: Decomposition of correlation between FDI and ENR, r_{13}

Components	Numerical quantity	Meaning
p_{31}	0.2736	Because FDI has direct effect to ENR
$p_{32} \cdot p_{21}$	−0.1789	Because FDI has direct effect to IND, and IND has direct effect to ENR
Total (r_{13})	0.0947	

FDI: Foreign direct investment, ENR: Energy use, IND: Industry growth, CO_2: Carbon dioxide

Equation (11) shows that there are direct effects of FDI and IND to ENR, the effect of FDI (p_{31} = 0.2736) is positive and based on the "meaningfulness" criteria of Land (1969) and Heisse (1969), p_{31} >0.05. Effect of IND (p_{32} = −0.4975) is negative, very significance, and meaningfulness. From the path diagram (Figure 6), the effect of FDI to ENR can be decomposed into direct and indirect effects as follows:
Direct effect p_{31} = 0.2736
Indirect effect $p_{21} \cdot p_{32}$ = (0.3597) (−0.4975) = −0.1789
Total effect $p_{31} + p_{21} \cdot p_{32}$ = 0.0947

While the effect of IND to ENR has only direct effect as p_{32} = −0.4975. The direct effect is negative.

Estimated model (3) is presented in Equation (12).

$$CO_2 = 0.0557\ IND + 0.9597\ ENR \quad 12)$$

Where, unexplained variation is $p_3 = \sqrt{1-0.8815} = 0.3442$.

Table 9: Decomposition of correlation between IND and ENR, r_{23}

Components	Numerical quantity	Meaning
$p_{31} \cdot p_{21}$	0.0984	Because FDI has direct effect to IND, and FDI has direct effect to ENR
p_{32}	−0.4975	Because IND has direct effect to ENR
Total (r_{23})	−0.3991	

FDI: Foreign direct investment, ENR: Energy use, IND: Industry growth, CO_2: Carbon dioxide

Table 10: Decomposition of correlation between IND and ENR, r_{24}

Components	Numerical quantity	Meaning
p_{42}	0.0557	Because IND has direct effect to CO_2 emissions
$p_{43} \cdot p_{31} \cdot p_{21}$	0.0944	Because FDI has direct effect to IND, and FDI has direct effect to ENR and ENR has direct effect to CO_2 emissions
$p_{43} \cdot p_{32}$	−0.4775	Because IND has direct effect to ENR and ENR has direct effect to CO_2
Total (r_{24})	−0.3273	

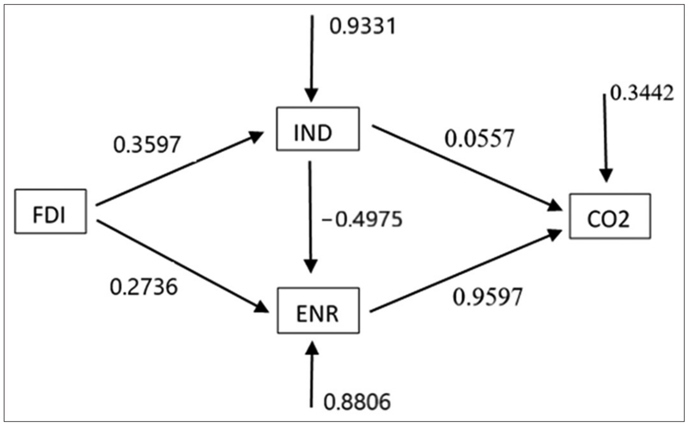
FDI: Foreign direct investment, ENR: Energy use, IND: Industry growth, CO_2: Carbon dioxide

Table 11: Decomposition of correlation between IND and ENR, r_{34}

Components	Numerical quantity	Meaning
p_{42}, $p_{31} \cdot p_{21}$	0.0055	Because FDI has direct effect to ENR, and FDI has direct effect to ENR and ENR has direct effect to CO_2 emissions
$p_{42} \cdot p_{32}$	−0.0277	Because IND has direct effect to ENR and IND has direct effect to CO_2
p_{43}	0.9597	Because ENR has direct effect to CO_2 emissions
Total (r_{34})	0.9375	

FDI: Foreign direct investment, ENR: Energy use, IND: Industry growth, CO_2: Carbon dioxide

Figure 6: Estimation of parameters of path analysis model



From Equation (12), it is clear that there are direct effect of IND and ENR to CO_2 emissions, the effect of IND ($p_{42} = 0.0557$) is positive and based on the "meaningfulness" criteria of Land (1969) and Heisse (1969), $p_{42} > 0.05$; while the effect of ENR ($p_{43} = 0.9597$) is positive and very significant and meaningfulness. From the path diagram (Figure 6), the effect of IND to CO_2 emissions can be decomposed into direct and indirect effects as follows:

Direct effect $p_{42} = 0.0557$

Indirect effect $p_{32}.p_{43} = (-0.4975)\ (0.9597) = -0.4774$

Total effect $p_{42} + p_{32}.p_{43} = -0.4217$

While the effect of ENR to CO_2 emissions has only direct effect, as big as $p_{43} = 0.9597$. The direct effect is positive.

Correlation of FDI and IND, $r_{12} = p_{21} = 0.3597$, means that the correlation is due to the direct effect of FDI to IND. The correlation between FDI and ENR, $r_{13} = p_{31} + p_{32}.p_{21}$, can be explained as presented in Table 8.

Correlation between IND and ENR, $r_{23} = p_{31}.p_{21} + p_{32}$, can be explained as shown in Table 9.

Correlation between IND and CO_2 ($r_{24} = p_{42} + p_{43}.p_{31}.p_{21} + p_{43}.p_{32}$) can be explained as demonstrated in Table 10.

Correlation between ENR and CO_2 ($r_{34} = p_{42}.p_{31}.p_{21} + p_{42}.p_{32} + p_{43}$) can be explained by Table 11.

4. CONCLUSION

This study investigates causal relationships among variables FDI, IND, ENR, and CO_2 emissions by using path analysis. Results of this study suggest that there is a direct effect of FDI to IND, there is direct effect of FDI and IND to ENR, and there is direct effect of IND and ENR to CO_2 emissions. Some direct effects are only meaningfulness, some are both very significant and meaningfulness. Path analysis is used to determine direct effects, indirect effects, and total effects from one variable to the other. Obtained result shows that FDI has direct effect to IND where the direct effect is 0.3597; FDI and IND have direct effect to ENR, where the direct effect of FDI to ENR and IND to ENR are 0.2736 and −0.4975 respectively. FDI also has indirect effect to ENR, where the indirect effect is −0.1789. IND and ENR have direct effect to CO_2 where the direct effect of IND to CO_2 and ENR to CO_2 are 0.0557 and 0.9597 respectively. IND also has indirect effect to CO_2 emissions, where the indirect effect is −0.4775. Path analysis also has been used to explain correlation between variables by decomposition of correlation into direct and indirect components, where this study explains decomposition of correlation between FDI and IND, between FDI and ENR, between IND and ENR, between IND and CO_2, and between ENR and CO_2 emissions.

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