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Fix effect sur to analyze economic growth in developed and developing countries

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Abstract: This study aims to identify the relationship between population density, inflation, and unemployment rates on the human development index, GNP, export-import, and urbanization in the developed and developing countries category using the Fix Effect Seemingly Unrelated Regression (FE SUR) with a dummy variable as the slope component. This research necessitates the development of the Seemingly Unrelated Regression model, specifically the Panel Seemingly Unrelated Regression (Panel SUR) model with a dummy variable as the slope component, due to the dynamic nature of the data and the fact that the same set of predictor variables explains the five response variables. The Panel, the Seemingly Unrelated Regression model with dummy variables, can accommodate research objectives where the SUR model can explain the influence between variables, differences in characteristics between countries can be explained by fixed effect models, and differences in the effect of population density, inflation, and unemployment rates on the human development index, GNP, exports imports and urbanization in the categories of developed and developing countries can be explained by slope dummy variables. The results showed that 98.46% of the diversity of response variables (human development index, GNP, exports, imports, and urbanization) could be explained by predictor variables (population density, inflation, and unemployment rate), while the other 1.54% was explained by other factors not included in the fixed effect SUR model. In addition, the results show that population density has a significant positive relationship with GNP, imports, and exports. However, there is a significant negative relationship between unemployment and GNP. There are large differences in the relationship between the unemployment rate and GNP in developed and developing countries, whereas in developed countries, there is a larger and negative relationship compared to developing countries.

Keywords: Fix Effect SUR; Panel SUR; Developed and Developing Country; World Economics; Economic Growth
JEL Classification: A10; B23; C33; F00; G00; O10

Introduction

To attain economic growth is a goal shared by all countries, but notably by developing countries. A country is considered developed if its economic level is high and evenly dispersed, its standard of living is high, and its technology is advanced. Developing countries have an average degree of social welfare and no economic equality (Heshmati et al., 2014). The benchmark for economic growth is economic growth and development. Every country must pursue economic growth on an annual basis in order to avoid economic crises and maintain a prosperous society. This is still a challenge in emerging countries, which strive for an improved economy through various economic activities and policies. Economic growth is a process because it is a stage that every country must experience; therefore, it requires long-term effort and cooperation between the community, government, and other concerned parties. The economic aspect, which includes international commerce and GNP, and the social aspect, which includes the human development index and urbanization, are the two primary lenses to view economic progress (Kuncoro, 2006).

Seemingly Unrelated Regression (SUR) is a form of multivariate regression that can accommodate residual correlations between equations (the structure of the variance between equations) so that each equation in the model seems to be independent or unrelated. However, the equations have relatedness (Alaba et al., 2019). To model the link between each predictor variable and each response variable, data from a single point in time are insufficient, due to the dynamic character of the data, in multivariate regression analysis of economic variables. Therefore, data is needed regarding variables related to several periods for each research object (panel data) so that the regression model obtained is better at describing the relationship of predictor variables to response variables so that a method that can accommodate these problems is developed, namely multivariate regression analysis on panel data. Panel data regression analysis is one of the developments that allows statistical users to analyze cause-and-effect relationships in the combined cross-section and time series data (Fitriani et al., 2021). The information obtained through panel data regression analysis becomes more informative because it considers the unit cross-section elements in several periods. Panel data regression analysis is a statistical method used to model the relationship of one or more predictor variables to response variables in several observed sectors of a research object over a certain period (Baltagi, 2008).

Over time, more complex statistical analysis methods are needed to allow statistical users to analyze the relationship of several predictor variables to more than one response variable in panel data. Therefore, a Seemingly Unrelated Regression Panel model was developed, capable of modeling the relationship of one or more predictor variables to more than one observed response variable of a research object over a certain time in panel data. The Seemingly Unrelated Regression Panel Model is one of the developments of multivariate regression analysis and panel data regression analysis that allows statistical users to analyze cause-and-effect relationships in the combined cross-section and time series data, not just one response variable. The Fix Effect SUR model is a form of the SUR Panel model which assumes that individuals have different characteristics. Through the Fix Effect Seemingly Unrelated Regression model, the information obtained becomes more informative and complex because in addition to considering elements of unit cross sections in several periods on many response variables at once, the Fix Effect Seemingly Unrelated Regression model also provides information about individual characteristics.

This study aims to develop a SUR model in which the data used is panel data, and a dummy variable will be added as a slope component and apply it to model the effect of economic variables (population density, inflation, and unemployment rate) on economic growth indicators (human development index, GNP, imports, exports, and urbanization). This study uses the SUR model because the five response variables (Human Development Index, GNP, Imports, Exports, and Urbanization) are explained by the same predictor variables (Population Density, Inflation, and Unemployment Rate). This study uses panel data because of the dynamic nature of the data so that data at one point in time is insufficient in modeling the effect of predictor variables on response variables. This study uses a fixed effect model because it is assumed that there are differences in characteristics between countries. In addition, the results of research by Wafiq and Suryanto (2021), Wau (2022), and research by A'yun and Khasanah (2022) state that the fixed effect model is better at modeling economic variables than the pooled and random effect models. This study uses a dummy variable as a slope component because it aims to determine differences in the effect of predictor variables on response variables in the categories of developed countries and developing countries. So that this research can be beneficial for developing countries in maximizing economic activities in their countries as well as aspects that need to be improved in order to have a high economic level like in developed countries. Apart from that, this research can be useful for developed countries to maintain their country's economic level.

Research Method

This study aims to develop the Seemingly Unrelated Regression (SUR) model where the data used is panel data and added a dummy variable as a slope component and apply it to model the effect of economic variables (population density, inflation, and unemployment rate) on economic growth indicators (human development index, GNP, imports, exports, and urbanization). The data used in this study are data on economic variables (population density, inflation, unemployment rate, human development index, GNP, imports, exports, and urbanization) in 145 countries in the world consisting of 110 developing countries and 35 developed countries in 2010 until 2019 sourced from the World Bank and IMF websites. This study uses the SUR model because the five response variables (Human Development Index, GNP, Imports, Exports, and Urbanization) are explained by the same predictor variables (Population Density, Inflation, and Unemployment Rate). This study uses panel data because of the data's dynamic nature of the data so data at one point in time is insufficient in modeling the effect of the predictor variable on the response variable.

Seemingly Unrelated Regression (SUR)

The SUR model uses m response variables as a function of p predictor variables which can be seen in equation (1) (Moon & Perron, 2006).

$$Y_{1i} = \beta_{10} + \beta_{11}X_{1i} + \beta_{12}X_{2i} + \cdots + \beta_{1p}X_{pi} + \beta_{20}(0) + \beta_{21}(0) + \cdots + \beta_{21}(0) + \cdots + \beta_{mp}(0) + \varepsilon_{1i}$$

$$Y_{2i} = \beta_{10}(0) + \beta_{11}(0) + \cdots + \beta_{1p}(0) + \beta_{20} + \beta_{21}X_{1i} + \beta_{22}X_{2i} + \cdots + \beta_{2p}X_{pi} + \beta_{m0}(0) + \beta_{m1}(0) + \ldots + \beta_{mp}(0) + \varepsilon_{2i}$$

⋮

$$Y_{mi} = \beta_{10}(0) + \beta_{11}(0) + \cdots + \beta_{1p}(0) + \cdots + \beta_{(m-1)p}(0) + \beta_{m0} + \beta_{m1}X_{1i} + \beta_{m2}X_{2i} + \cdots + \beta_{mp}X_{pi} + \varepsilon_{mi} \quad (1)$$

Equation (1) can be simplified to equation (2).

$$Y_{li} = \beta_{l0} + \sum_{j=1}^{p} \beta_{lj}X_{ji} + \varepsilon_{li} ; i = 1, 2, \ldots, n ; l = 1,2, \ldots, \mathrm{m} ; \mathrm{j} = 1,2, \ldots, p \quad (2)$$

where:
Y_{li}= i-th value of the l-th response variable
X_{ji}= i-th value of the j-th predictor variable
β_{l0}= intercept the response variable to-l
β_{lj}= parameter of the jth predictor variable to the l-th response variable
ε_{li}= i-th value of the random error variable on the l-th response variable
n= sample size
m= number of response variables
p= number of predictor variables

The form of the SUR equation in the matrix can be seen in equation (3) (Pramoedyo et al., 2020).

$$\boldsymbol{Y}_{mn\times 1} = \boldsymbol{X}_{mn\times m(p+1)}\boldsymbol{\beta}_{m(p+1)\times 1} + \boldsymbol{\varepsilon}_{mn\times 1} \quad (3)$$

Fix Effect Seemingly Unrelated Regression (FE SUR)

In the fixed effects model, it is assumed that there is a relationship between the characteristics of the object (α_{mi}) and the predictor variables for each response variable. The Fix Effect Seemingly Unrelated Regression model is presented in equation (4) (Xu et al., 2018).

$$Y_{1it} = \beta_{01i} + \beta_{11}X_{1it} + \beta_{12}X_{2it} + \cdots + \beta_{1p}X_{pit} + \varepsilon_{1it}$$

$$Y_{2it} = \beta_{02i} + \beta_{21}X_{1it} + \beta_{22}X_{2it} + \cdots + \beta_{2p}X_{pit} + \varepsilon_{2it}$$

$$\vdots$$

$$Y_{mit} = \beta_{0mi} + \beta_{m1}X_{1it} + \beta_{m2}X_{2it} + \cdots + \beta_{mp}X_{pit} + \varepsilon_{mit} \quad (4)$$

Slope Dummy Fix Effect SUR

The Slope Dummy Fix Effect Seemingly Unrelated Regression model is presented in equation (5).

$$Y_{1it} = \alpha_{10i} + \alpha_{112}(D_{2i} \times X_{1it}) + \alpha_{113}(D_{3i} \times X_{1it}) + \cdots + \alpha_{11k}(D_{ki} \times X_{1it}) + \alpha_{122}(D_{2i} \times X_{2it}) + \alpha_{123}(D_{3i} \times X_{2it}) + \cdots + \alpha_{12k}(D_{ki} \times X_{2it}) + \cdots + \alpha_{1p2}\big(D_{2i} \times$$

$X_{pit}) + \alpha_{1p3}(D_{3i} \times X_{pit}) + \cdots + \alpha_{1pk}(D_{ki} \times X_{pit}) + \beta_{11}X_{1it} + \beta_{12}X_{2it} + \cdots + \beta_{1p}X_{pit} + \varepsilon_{1it}$

$Y_{2it} = \alpha_{20i} + \alpha_{212}(D_{2i} \times X_{1it}) + \alpha_{213}(D_{3i} \times X_{1it}) + \cdots + \alpha_{21k}(D_{ki} \times X_{1it}) + \alpha_{222}(D_{2i} \times X_{2it}) + \alpha_{223}(D_{3i} \times X_{2it}) + \cdots + \alpha_{22k}(D_{ki} \times X_{2it}) + \cdots + \alpha_{2p2}(D_{2i} \times X_{pit}) + \alpha_{2p3}(D_{3i} \times X_{pit}) + \cdots + \alpha_{2pk}(D_{ki} \times X_{pit}) + \beta_{21}X_{1it} + \beta_{22}X_{2it} + \cdots + \beta_{2p}X_{pit} + \varepsilon_{2it}$

$\vdots$

$Y_{mit} = \alpha_{m0i} + \alpha_{m12}(D_{2i} \times X_{1it}) + \alpha_{m13}(D_{3i} \times X_{1it}) + \cdots + \alpha_{m1k}(D_{ki} \times X_{1it}) + \alpha_{m22}(D_{2i} \times X_{2it}) + \alpha_{m23}(D_{3i} \times X_{2it}) + \cdots + \alpha_{m2k}(D_{ki} \times X_{2it}) + \cdots + \alpha_{mp2}(D_{2i} \times X_{pit}) + \alpha_{mp3}(D_{3i} \times X_{pit}) + \cdots + \alpha_{mpk}(D_{ki} \times X_{pit}) + \beta_{m1}X_{1it} + \beta_{m2}X_{2it} + \cdots + \beta_{mp}X_{pit} + \varepsilon_{mit}$ (5)

SUR Model Assumptions

Several assumptions must be fulfilled in the Seemingly Unrelated Regression (SUR) model, namely the assumption of non-multicollinearity between predictor variables and the correlation of errors between equations.

Checking Non-multicollinearity between Predictor Variables

One of the regression assumptions is that there is no relationship between predictor variables. The hypothesis underlying the non-multicollinearity assumption test is

H_0: there is no multicollinearity between predictor variables vs

H_1: there is multicollinearity between predictor variables

If H_0 is true, then the VIF statistic is used in the equation (6)

$$VIF_j = \frac{1}{1-R_j^2} \quad (6)$$

where:
VIF_j = VIF value of the j-th predictor variable
Accept H_0 if VIF_j statistic < 10 (Bowerman & O'Connel, 1990).

Testing Correlation of Errors between Equations Assumptions

The purpose of testing the assumptions of error correlation is to find out whether there is an error correlation between equations, with the hypothesis:

$H_0 : s_{ij} = 0 \; for \; all \; i \neq j; i = 1, 2, \ldots, m; j = 1, 2, \ldots, m$ (there is no error correlation between equations) vs

H_1: $at \; least \; one \; ij \; where \; s_{ij} \neq 0$ (there is an error correlation between equations)

If H_0 is true, then the Lagrange Multiplier test statistic is used in the equation (7).

$$LM = nt\sum_{i=1}^{m}\sum_{j=1}^{i-1} s_{ij}^2 \sim \chi^2_{\frac{m(m-1)}{2}} \qquad (7)$$

where:
s_{ij} = correlation of the residuals of the i-th equation and the j-th equation
n = sample size
t = period of time
m = number of equations

Accept H_0 if LM statistics < $\chi^2_{\alpha,\frac{m(m-1)}{2}}$ or $P\left(LM < \chi^2_{\alpha,\frac{m(m-1)}{2}}\right) > \alpha$ (Greene, 2012).

Parameter Estimation of SUR Model with GLS

Parameters in the SUR Panel model can be estimated using Generalized Least Square (GLS) by minimizing the sum of squared errors where it is assumed that matrix V (OLS residual matrix of variance) is known as follows (Zellner, 1962; Nisak, 2016; Biørn, 2004).

$$\begin{gathered}
\hat{\varepsilon}'\hat{\varepsilon} = (Y - X\hat{\beta})'V^{-1}(Y - X\hat{\beta}) \\
\hat{\varepsilon}'\hat{\varepsilon} = (Y' - X'\hat{\beta}')V^{-1}(Y - X\hat{\beta}) \\
\hat{\varepsilon}'\hat{\varepsilon} = Y'V^{-1}Y - Y'V^{-1}X\hat{\beta} - YV^{-1}X'\hat{\beta}' + X\hat{\beta}V^{-1}X'\hat{\beta}' \\
\hat{\varepsilon}'\hat{\varepsilon} = Y'V^{-1}Y - 2X'V^{-1}\hat{\beta}'Y + X\hat{\beta}V^{-1}X'\hat{\beta}' \\
\frac{\partial(\hat{\varepsilon}'\hat{\varepsilon})}{\partial(\hat{\beta})} = \frac{\partial\left(Y'V^{-1}Y - 2X'V^{-1}\hat{\beta}'Y + X\hat{\beta}V^{-1}X'\hat{\beta}'\right)}{\partial(\hat{\beta})} = 0 \\
\frac{\partial(\hat{\varepsilon}'\hat{\varepsilon})}{\partial(\hat{\beta})} = -2X'V^{-1}Y + 2X'V^{-1}X\hat{\beta} = 0 \\
-X'V^{-1}Y + X'V^{-1}X\hat{\beta} = 0 \\
X'V^{-1}X\hat{\beta} = X'V^{-1}Y \\
\hat{\beta} = (X'V^{-1}X)^{-1}X'V^{-1}Y
\end{gathered}$$

(8)

where:
Y = response variable vector is mn × 1 in size
X = predictor variable matrix of size mn × m(p+1)
V = error variance matrix of size mn × mn
$\hat{\beta}$ = parameter estimator vector of size m(p+1) × 1
m = number of response variables
n = sample size
p = number of predictor variables

Simultaneous Testing

The purpose of testing is to find out the relationship between the predictor variables simultaneously with the response with the hypothesis:

$H_0: \beta_{11} = \cdots = \beta_{1p} = \cdots = \beta_{2p} = \cdots = \beta_{mp} = 0$ vs

$H_1: there\ is\ one\ or\ more\ lj\ where \beta_{lj} \neq 0;$
$l = 1,2, \dots, m; j = 1,2, \dots, p$

If H_0 is true, then the F test statistic is used in the equation (9).

$$F = \frac{Mean\ square\ regression}{Mean\ square\ error} \sim F_{mp,mn-mp} \quad (9)$$

Accept H_0 if F >$F_{mp,mn-mp}^{\alpha/2}$ or $P\left(F < F_{mp,mn-mp}^{\alpha/2}\right) > \alpha$ (Effendi, et al., 2020).

Partial Testing

The purpose of doing partial testing is to find out the relationship of each predictor variable individually to the response with the hypothesis:

$H_0: \beta_{lj} = 0$ vs

$H_1: \beta_{lj} \neq 0;\ l = 1,2, \dots, m; j = 1,2, \dots, p$

If H_0 is true, then the t-test statistic is used in the equation (10).

$$t = \frac{\hat{\beta}_{lj}}{S(\hat{\beta}_{lj})} \sim t_{mn-mp}; l = 1,2, \dots, m; j = 1,2, \dots, p \quad (10)$$

where:
$\hat{\beta}_{lj}$ = parameter estimator β_{lj}
$S(\hat{\beta}_{lj})$ = standard error of parameter estimator β_{lj}
Accept H_0 if t < $t_{mn-mp}^{\alpha/2}$ or $2P\left(t < t_{mp,mn-mp}^{\alpha/2}\right) > \alpha$ (Fernandes and Solimun, 2019).

Research Procedure

The procedure of this research is as follows.
1. Checking the relationship between predictor variables (assuming non-multicollinearity) using VIF statistics as in equation (6)
2. Estimating the parameters of the Fix Effect SUR model using the general least squares (GLS) method in equation (8)
3. Checking the correlation of errors between equations assumption using the Lagrange Multiplier test statistic as in equation (7)
4. Testing the relationship of the predictor variables to the response variables of the Fix Effect SUR model simultaneously as in equation (9) and individually as in equation (10)
5. Checking the feasibility of the Fix Effect SUR model using the coefficient of determination
6. Interpretation of the model obtained

Result and Discussion

Fix Effect SUR Parameter Estimation

After analysis, the parameter estimators of the Fix Effect SUR model are obtained as in Table 1

Table 1 Fix Effect SUR Parameter Estimation

Variable	Parameter Estimation	P-Value	Variable	Parameter Estimation	P-Value
X1.1	0.001	0.9986	X1D.1	0.005	0.9998
X2.1	0	0.9999	X2D.1	-0.003	0.9996
X3.1	-0.002	0.9993	X3D.1	-0.001	0.9998
X1.2	28.68	<0.0001	X1D.2	12.831	0.4175
X2.2	-0.055	0.8986	X2D.2	-9.768	0.0817
X3.2	-10.358	0.0001	X3D.2	-16.019	<0.0001
X1.3	2.952	<0.0001	X1D.3	11.711	0.4593
X2.3	-0.009	0.9838	X2D.3	3.776	0.501
X3.3	-2.195	0.3941	X3D.3	-4.474	0.2549
X1.4	2.657	0.0001	X1D.4	19.459	0.2188
X2.4	0.002	0.9955	X2D.4	0.471	0.9331
X3.4	-2.019	0.4331	X3D.4	-4.718	0.2299
X1.5	0.103	0.8778	X1D.5	0.169	0.9915
X2.5	-0.009	0.9825	X2D.5	-0.081	0.9884
X3.5	-0.072	0.9778	X3D.5	-0.015	0.9970

Based on Table 1, the Fix Effect SUR model is obtained as in equation (11).

$$HDI_{it} = \alpha_{1i} + 0.005(D_{2i} \times Population\ Density_{it}) - 0.003(D_{2i} \times Inflation_{it}) - 0.001(D_{2i} \times Unemployment\ Rate_{it}) + 0.001 Population\ Density_{it} + 0 Inflation_{it} - 0.002 Unemployment\ Rate_{it}$$

$$GNP_{it} = \alpha_{2i} + 12.931(D_{2i} \times Population\ Density_{it}) - 9.768(D_{2i} \times Inflation_{it}) - 16.019(D_{2i} \times Unemployment\ Rate_{it}) + 28.68 Population\ Density_{it} - 0.055 Inflation_{it} - 10.358 Unemployment\ Rate_{it}$$

$$Import_{it} = \alpha_{3i} + 11.711(D_{2i} \times Population\ Density_{it}) + 3.776(D_{2i} \times Inflation_{it}) - 4.474(D_{2i} \times Unemployment\ Rate_{it}) + 2.952 Population\ Density_{it} - 0.009 Inflation_{it} - 2.195 Unemployment\ Rate_{it}$$

$$Export_{it} = \alpha_{4i} + 19.459(D_{2i} \times Population\ Density_{it}) + 0.471(D_{2i} \times Inflation_{it}) - 4.718(D_{2i} \times Unemployment\ Rate_{it}) + 2.657 Population\ Density_{it} + 0.002 Inflation_{it} - 2.019 Unemployment\ Rate_{it}$$

$$Urbanization_{it} = \alpha_{5i} + 0.169(D_{2i} \times Population\ Density_{it}) - 0.081(D_{2i} \times Inflation_{it}) - 0.015(D_{2i} \times Unemployment\ Rate_{it}) + 0.103Population\ Density_{it} - 0.009Inflation_{it} - 0.072Unemployment\ Rate_{it} \quad (11)$$

Checking Non-Multicollinearity Assumption

Examination of non-multicollinearity assumptions is carried out to determine the relationship between predictor variables whether there is multicollinearity or not. The results of checking the non-multicollinearity assumptions between predictor variables are presented in Table 2.

Table 2 Results of Checking of Non-Multicollinearity Assumptions

The j-th Predictor Variable	VIF_j
Population Density	1.008598
Inflation	1.001373
Unemployment Rate	1.008285

Through Table 2, VIF statistics are obtained for population density (1.008598), inflation (1.001373), and unemployment rate (1.008285) < 10. Therefore, sufficient evidence is obtained to accept H_0 so that it can be concluded that there is no multicollinearity between predictor variables and non-multicollinearity assumption between predictor variables in the fixed effect SUR model has been fulfilled.

Testing Correlation of Errors between Equation Assumptions

Testing the assumption of error correlation between equations is carried out to determine whether the errors between equations in the SUR model are correlated. The results of testing the correlation between errors of equation assumption are presented in Table 3.

Table 3 Results of Testing of Correlation of Errors between Equations Assumption in the SUR Fixed Effect Model

The i-th and j-th equation	$r_{i,j}$	$r_{i,j}^2$
First and second equation	-0.108	0.012
First and third equation	-0.003	<0.001
First and 4th equation	-0.018	<0.001
First and 5th equation	0.671	0.450
Second and third equation	0.753	0.567
Second and 4th equation	0.719	0.517
Second and 5th equation	0.026	0.001
Third and 4th equation	0.918	0.843
Third and 5th equation	0.058	0.003
4th and 5th equation	0.041	0.002
$LM = nt\sum_{i=1}^{m}\sum_{j=1}^{i-1} r_{ij}^2$		3472.873

Table 3 shows the LM test statistics for the fixed effect SUR model (3472.873) > $\chi^2_{0.05,10}$ (3.94) or p-value (0) > α (0.05) are obtained. Therefore, sufficient evidence is obtained to reject H_0 so that it can be concluded that there is an error correlation between equations and the assumption of an error correlation between equations in the fixed effect SUR model has been fulfilled.

F Test

Simultaneous testing using the F test was carried out to determine whether population density, inflation, and unemployment rates simultaneously affect the human development index, GNP, imports, exports, and urbanization in the fixed effect SUR model. The analysis results show that the F test statistic for the fixed effect SUR model is 92692.37, which is greater than $F_{755,1093995}$ (1.96). Therefore, it can be decided that H_0 is rejected so that it can be concluded that simultaneously the SUR fix effect model is significant or at least there is one predictor variable (population density, inflation or unemployment rate) that has a significant relationship to the response variable (human development index, GNP, import, export or urbanization).

t Test

Tests using the t test were carried out to determine whether individual population density, inflation, and unemployment rates are significantly related to the human development index, GNP, imports, exports, and urbanization in the fixed SUR effect model. Several variables have a significant relationship through Table 1: population density to GNP, unemployment rate to GNP, differences in the effect of the unemployment rate on GNP in developed and developing countries, population density on imports, and population density on exports. Meanwhile, there is no significant relationship between predictor variables and other response variables.

Fix Effect SUR Model Interpretation

Through the results of the analysis, it is obtained that the general fix effect SUR model for this research in equation (11).

$$HDI_{it} = \alpha_{1i} + 0.005(D_{2i} \times Population\ Density_{it}) - 0.003(D_{2i} \times Inflation_{it}) - 0.001(D_{2i} \times Unemployment\ Rate_{it}) + 0.001 Population\ Density_{it} + 0 Inflation_{it} - 0.002 Unemployment\ Rate_{it}$$

$$GNP_{it} = \alpha_{2i} + 12.931(D_{2i} \times Population\ Density_{it}) - 9.768(D_{2i} \times Inflation_{it}) - 16.019(D_{2i} \times Unemployment\ Rate_{it}) + 28.68 Population\ Density_{it} - 0.055 Inflation_{it} - 10.358 Unemployment\ Rate_{it}$$

$$Import_{it} = \alpha_{3i} + 11.711(D_{2i} \times Population\ Density_{it}) + 3.776(D_{2i} \times Inflation_{it}) - 4.474(D_{2i} \times Unemployment\ Rate_{it}) + 2.952 Population\ Density_{it} - 0.009 Inflation_{it} - 2.195 Unemployment\ Rate_{it}$$

$$Export_{it} = \alpha_{4i} + 19.459(D_{2i} \times Population\ Density_{it}) + 0.471(D_{2i} \times Inflation_{it}) - 4.718(D_{2i} \times Unemployment\ Rate_{it}) + 2.657Population\ Density_{it} + 0.002Inflation_{it} - 2.019Unemployment\ Rate_{it}$$

$$Urbanization_{it} = \alpha_{5i} + 0.169(D_{2i} \times Population\ Density_{it}) - 0.081(D_{2i} \times Inflation_{it}) - 0.015(D_{2i} \times Unemployment\ Rate_{it}) + 0.103Population\ Density_{it} - 0.009Inflation_{it} - 0.072Unemployment\ Rate_{it} \quad (12)$$

Through this model, the SUR fix effect model for developing countries (D_{2i}=0) is obtained as follows.

$$HDI_{it} = \alpha_{1i} + 0.001Population\ Density_{it} + 0.000Inflation_{it} - 0.002Tingkat\ Pengangguran_{it}$$

$$GNP_{it} = \alpha_{2i} + 28.680Population\ Density_{it} - 0.055Inflation_{it} - 10.358Unemployment\ Rate_{it}$$

$$Import_{it} = \alpha_{3i} + 2.952Population\ Density_{it} - 0.009Inflation_{it} - 2.195Unemployment\ Rate_{it}$$

$$Export_{it} = \alpha_{4i} + 2.657Population\ Density_{it} + 0.002Inflation_{it} - 2.019Unemployment\ Rate_{it}$$

$$Urbanization_{it} = \alpha_{5i} + 0.103Population\ Density_{it} - 0.009Inflation_{it} - 0.072Unemployment\ Rate_{it} \quad (13)$$

Meanwhile, the SUR fixed effect model for developed countries (D_{2i}=1) is as follows.

$$HDI_{it} = \alpha_{1i} + (0.001 + 0.005)Population\ Density_{it} + (0.000 - 0.003)Inflation_{it} + (-0.002 - 0.001)Unemployment\ Rate_{it} = \alpha_{1i} + 0.006Population\ Density_{it} - 0.003Inflation_{it} - 0.003Unemployment\ Rate_{it}$$

$$GNP_{it} = \alpha_{2i} + (28.680 + 12.931)Population\ Density_{it} + (-0.055 - 9.768)Inflation_{it} + (-10.358 - 16.019)Unemployment\ Rate_{it} = \alpha_{2i} + 41.611Population\ Density_{it} - 9.823Inflation_{it} - 26.377Unemployment\ Rate_{it}$$

$$Import_{it} = \alpha_{3i} + (2.952 + 11.711)Population\ Density_{it} + (-0.009 + 3.776)Inflation_{it} + (-2.195 - 4.474)Unemployment\ Rate_{it} = \alpha_{3i} + 14.663Population\ Density_{it} + 3.767Inflation_{it} - 6.669Unemployment\ Rate_{it}$$

$$Export_{it} = \alpha_{4i} + (2.657 + 19.459)Population\ Density_{it} + (0.002 + 0.471)Inflation_{it} + (-2.019 - 4.718)Unemployment\ Rate_{it} = \alpha_{4i} + 22.116Population\ Density_{it} + 0.473Inflation_{it} - 6.737Unemployment\ Rate_{it}$$

$$Urbanization_{it} = \alpha_{5i} + (0.103 + 0.169)Population\ Density_{it} + (-0.009 - 0.081)Inflation_{it} + (-0.072 - 0.015)Unemployment\ Rate_{it} = \alpha_{5i} + 0.272Population\ Density_{it} - 0.900Inflation_{it} - 0.087Unemployment\ Rate_{it} \quad (14)$$

Through the SUR fix effect model in developed and developing countries, it can be seen that every increase of 1 million population, the human development index in developing countries increases by 0.001, while the human development index in developed countries increases by 0.006. For every 1 million population increases, GNP in developing countries increases by US$ 26.68 billion, while GNP in developed countries increases by US$ 41.611 billion. For every 1 million increase in population, imports to developing countries increased by US$ 2.952 billion, while imports to developed countries increased by US$ 14.633 billion. For every 1 million increase in population, exports to developing countries increased by US$ 2.657 billion, while exports to developed countries increased by US$ 12.116 billion. For every increase of 1 million population, urbanization in developing countries increases by 0.103%, while urbanization in developed countries increases by 0.272%.

With every 1% increase in the inflation rate, the human development index in developing countries does not change at all, while the human development index in developed countries decreases by 0.003. For every 1% increase in the inflation rate, GNP in developing countries decreased by US$ 0.055 billion, while GNP in developed countries decreased by US$ 9.823 billion. For every 1% increase in the inflation rate, imports to developing countries decreased by US$ 0.009 billion, but imports to developed countries increased by US$ 3.767 billion. For every 1% increase in the inflation rate, exports to developing countries increased by US$ 0.002 billion, while exports to developed countries increased by US$ 0.473 billion. For every 1% increase in the inflation rate, urbanization in developing countries decreases by 0.009%, while urbanization in developed countries decreases by 0.09%.

If the unemployment rate increases by 1%, the human development index in developing countries will decrease by 0.002, while the human development index in developed countries will decrease by 0.003. If the unemployment rate increases by 1%, GNP in developing countries will decrease by US$ 10.358 billion, while GNP in developed countries will decrease by US$ 26.377 billion. If the unemployment rate increases by 1%, imports in developing countries will decrease by US$ 2.195 billion, while imports in developed countries will decrease by US$ 6,669 billion. If the unemployment rate increases by 1%, exports to developing countries will decrease by US$ 2.019 billion, while exports to developed countries will decrease by US$ 6.737 billion. If the unemployment rate increases by 1%, urbanization in developing countries will decrease by 0.072%, while urbanization in developed countries will decrease by 0.087%.

Models for Developing Countries (Example: Jamaica)

$$HDI_{it} = 0.754 + 0.001Population\ Density_{it} + 0Inflation_{it} - 0.002Unemployment\ Rate_{it}$$

$$GNP_{it} = 59.75 + 28.68Population\ Density_{it} - 0.055Inflation_{it} - 10.358Unemployment\ Rate_{it}$$

$$Import_{it} = 25.899 + 2.952Population\ Density_{it} - 0.009Inflation_{it} - 2.195Unemployment\ Rate_{it}$$

$$Export_{it} = 21.943 + 2.657Population\ Density_{it} + 0.002Inflation_{it} - 2.019Unemployment\ Rate_{it}$$

$$Urbanization_{it} = 55.415 + 0.103Population\ Density_{it} - 0.009Inflation_{it} - 0.072Unemployment\ Rate_{it}$$

Through the model above, it can be seen that the average human development index for Jamaica is 0.754, the average GNP for Jamaica is US$ 59.75, the average import for Jamaica is US$ 25.899, the average export for Jamaica is US$ 21.943, the average -the average urbanization rate for the country of Jamaica is 55.415%. Every increase of 1 million population will increase the human development index in Jamaica by 0.001, increase GNP in Jamaica by US$ 28.68 billion, imports in Jamaica by US$ 2.952 billion, exports in Jamaica by US$ 2.657 billion, and urbanization in Jamaica by 0.103%. Every increase of 1 unit of inflation will not change the human development index in Jamaica in the slightest, reducing GNP by US$ 0.055 billion, reducing imports in Jamaica by US$ 0.009 billion, reducing exports in Jamaica by US$ 0.002 billion, and reducing urbanization in Jamaica by 0.009 %. Every 1% increase in the unemployment rate will reduce the human development index in Jamaica by 0.002, reduce GNP in Jamaica by US$ 10.358 billion, reduce imports in Jamaica by US$ 2.195 billion, reduce exports in Jamaica by US$ 2.019 billion, and reduce urbanization in Jamaica by 0.072%.

Model for Developed Countries (Example: Norway)

$$HDI_{it} = 0.935 + 0.006Population\ Density_{it} - 0.003Inflation_{it} - 0.003Unemployment\ Rate_{it}$$

$$GNP_{it} = 351.095 + 41.611Population\ Density_{it} - 9.823Inflation_{it} - 26.377Unemployment\ Rate_{it}$$

$$Import_{it} = 77.559 + 14.663Population\ Density_{it} + 3.767Inflation_{it} - 6.669Unemployment\ Rate_{it}$$

$$Export_{it} = 82.122 + 22.116Population\ Density_{it} + 0.473Inflation_{it} - 6.737Unemployment\ Rate_{it}$$

$$Urbanization_{it} = 79.987 + 0.272Population\ Density_{it} - 0.9Inflation_{it} - 0.087Unemployment\ Rate_{it}$$

Through the model above, it can be seen that the average human development index for Norway is 0.935, the average GNP for Norway is US$ 351.095, the average import for Norway is US$ 77.559, the average export for Norway is US$ 82.122, the average -the average urbanization rate for Norway is 79.987%. Every increase of 1 million population will increase the human development index in Norway by 0.006, increase GNP in Norway by US$ 41.633 billion, increase imports in Norway by US$ 14.633 billion, increase exports in Norway by US$ 22.116 billion, and increasing urbanization in Norway 0.272%. Every 1 unit increase in inflation will reduce the human development index in Norway by 0.003, reduce GNP in Norway by US$ 9.823 billion, increase imports in Norway by US$ 3.767 billion, increase exports in Norway by US$ 0.473 billion, and reduce urbanization in Norway by 0.9%. Every 1% increase in the unemployment rate will reduce the human development index in Norway by 0.003, reduce GNP in Norway by US$ 26.377 billion, reduce imports in Norway by US$ 6.669 billion, reduce exports in Norway by US$ 6.737 billion, and reduce urbanization in Norway by 0.087%.

The effect of population density on the human development index in developed and developing countries is not in line with research conducted by Adim (2021), where the more the population, the human development index will decrease because if the population in an area is denser, the community tends to be less prosperous. However, the effect of population density on the human development index is in line with the research of Antara and Suryana (2020), where the more the population, the human development index will be because if the population in an area is denser than the development and facilities in that area tend to be more numerous than areas with a small population. The effect of population density on imports in developed and developing countries is in line with research conducted by Mahardika and Yuliarmi (2018), where the more people there are, the more imports in a country will also increase because the more people in a country, the goods/services that will be imported. Government imports are also increasing, and many people carry out import transactions of goods/services from abroad, thereby increasing the value of imports.

The effect of population density on exports in developed and developing countries is in line with research conducted by Morrison (1977), where the more the population, the exports in a country will also increase because the more people in a country, the more goods/services that the government will export. There are also more and more people going abroad who carry out transactions for the export of goods/services from abroad, thus increasing the value of exports.

The effect of inflation on the human development index in developed countries is in line with research conducted by Pangesti and Susanto (2018), where the higher the inflation, the higher the price of goods on the market, so that many people cannot afford it and in the end people's welfare decreases. The effect of inflation on GNP in developed and developing countries is in line with research conducted by Silitonga (2021), where inflation causes prices of goods to increase and people's purchasing power to decrease so that state income also decreases. The effect of inflation on imports in developed countries is in line with the theory put forward by Sukirno (2,008), where the higher the inflation, the cheaper the price of imported goods (the price of goods abroad is cheaper than domestically) so that the government and society tend to import goods/services from abroad.

The effect of the unemployment rate on the human development index in developed and developing countries is in line with research conducted by Ningrum et al. (2020), where the higher the unemployment rate, the more social welfare will decrease because unemployed people cannot fulfill their needs. The effect of the unemployment rate on GNP in developed and developing countries is in line with research conducted by Novriansyah (2018), where the higher the unemployment rate, the lower state income because a large number of unemployed people will not increase state income, so that state income tends to decrease when more and more people are unemployed.

Coefficient Determination

Through the analysis results, it is obtained that the R^2 statistic for the general fix effect model in equation (11) is 0.9846, which means that the Fix Effect SUR model is very good where 98.46% of the variety of the values of the human development index, GNP, imports, exports, and urbanization can be explained by population density, inflation, and the unemployment rate, while the remaining 1.54% explained by other variables that are not included in the Fix Effect SUR model. The results of the t test and Table 1 showed that only 5 of the 30 research hypotheses were significant. However, the R2 statistic shows a very high value where population density, inflation, and unemployment rates explain 98.46% of the variation in the human development index values, GNP, imports, exports, and urbanization. This indicates that there are individual effects in each country (country characteristics) which causes the Fix Effect SUR model to be very good at modeling the relationship between population density, inflation, and unemployment rates on the human development index, GNP, imports, exports, and urbanization in developed and developing countries.

Conclusion

This study aims to develop the Seemingly Unrelated Regression (SUR) model where the data used is panel data and added a dummy variable as a slope component and apply it to model the effect of economic variables (population density, inflation, and unemployment rate) on economic growth indicators (human development index, GNP, imports, exports, and urbanization). The data used in this study are data on economic variables (population density, inflation, unemployment rate, human development index, GNP, imports, exports, and urbanization) in 145 countries in the world consisting of 110 developing countries and 35 developed countries in 2010 until 2019 sourced from the World Bank and IMF websites.

Through testing the significance of the parameters separately in the SUR fix effect model in Table 1, it is found that population density has a significant positive effect on GNP, imports, and exports. In addition, the unemployment rate and GNP have a significant negative effect. Through testing the significance of the parameters separately in the SUR fix effect model in Table 1, it was found that there were not many significant differences between the magnitude of the relationship between population density, inflation, and the unemployment rate on the human development index, GNP, imports, exports and urbanization in developed and developing countries. In addition, it is found that there are differences in the effect of the unemployment rate on GNP in the categories of developed and developing countries, where for each increase in the same unemployment rate, the decrease in GNP in developed countries is greater than with developing countries.

Therefore, all countries are expected to pay attention to population density and the unemployment rate because it can affect the country's GNP, imports, and exports. In addition, it is hoped that developing countries will be able to carry out population efficiency so that with an increasing population, the influence on GNP, imports, and exports will be greater like in developed countries where most of the population of developed countries has good quality human resources. On the other hand, it is hoped that developing countries will be able to add decent jobs to the population in order to reduce the unemployment rate so that the influence on GNP, imports, and exports will be greater like in developed countries where most of the population of developed countries are already working and have decent jobs and salaries.

This study only uses balanced panel data to facilitate research. It is hoped that further research can develop this research with the Seemingly Unrelated Regression model on unbalanced panel data so that all countries with incomplete data can be included in the model.

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References

Adim, A. (2021). Pengaruh Jumlah Penduduk dan Pendapatan Perkapita Terhadap Indeks Pembangunan Manusia (IPM) Provinsi Jawa Timur Kurun 2017-2019. *Jurnal Ekonomi dan Bisnis, 22*(1), 1-11. Retrieved from http://jurnal.unissula.ac.id/index.php/ekobis/article/view/13388

Alaba, O. O., Adepoju, A. A., & Olaomi, O. E. (2019). Seemingly Unrelated Regression with Decomposed Variance-Covariance Matrix: A Bayesian Approach. *Journal of the Nigerian Association of Mathematical Physics, 51*, 137-144.

Antara, I. M. Y., & Suryana, I. M. E. 2020. Pengaruh Tingkat Kepadatan Penduduk Terhadap Indeks Pembangunan Manusia di Provinsi Bali. *Media Komunikasi Geografi, 21*(1), 63-73. https://doi.org/10.23887/mkg.v21i1.22958

A'yun, I. Z., & Khasanah, U. 2022. The Impact of Economic Growth and Trade Openness on Environmental Degradation: Evidence from A Panel of ASEAN Countries. *Jurnal Ekonomi & Studi Pembangunan, 23*(1), 81-92. https://doi.org/10.18196/jesp.v23i1.13881

Baltagi, B. H. (2008). *Econometrics Analysis of Panel Data (4th Edition*). New York: John Wiley and Sons.

Biørn, E. (2004). Regression systems for unbalanced panel data: a stepwise maximum likelihood procedure. *Journal of Econometrics, 122*(2), 281–291. https://doi.org/10.1016/j.jeconom.2003.10.023

Bowerman, B. L. & O'connel, R. T. (1990). *Linear Statistical Models and Applied Approach (2nd Edition*). Boston: PWS-KNT.

Effendi, A., Wardhani, N. W. S., Fitriani, R., & Sumarningsih, E. (2020). *Analisis Regresi: Teori dan Implementasi dengan R.* Malang: Universitas Brawijaya Press.

Fernandes, A. A. R., & Solimun, S. (2019). *Analisis Regresi dalam Pendekatan Fleksibel: Ilustrasi dengan Paket Program R.* Malang: Universitas Brawijaya Press.

Fitriani, R., Nurjannah & Pusdikasari, Z. F. (2021). *Dasar-Dasar Ekonometrika dan Terapannya dengan GRETL.* Malang: Universitas Brawijaya Press.

Greene, W. H. (2012). *Econometric Analysis (7th ed.).* Boston, MA: Pearson Education.

Heshmati, A., Kim, J., & Park, D. (2014). Fiscal Policy and Inclusive Growth in Advanced Countries: Their Experience and Implications for Asia. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.2558908

Kuncoro, M. (2006). *Ekonomika Pembangunan: Teori. Masalah, dan Kebijakan, Edisi, 4*. Jakarta: Penerbit Salemba Empat.

Mahardika, A., & Yuliarmi, N. (2018). Pengaruh Jumlah Penduduk, Produksi, PDB dan Kurs Dollar Amerika Serikat Terhadap Impor Cabai Indonesia. *E-Jurnal Ekonomi Pembangunan Universitas Udayana*, 7(3), 502 - 530. Retrieved from https://ojs.unud.ac.id/index.php/eep/article/view/37842

Moon, H. R., & Perron, B. (2008). Seemingly Unrelated Regressions. *The New Palgrave Dictionary of Economics,* 1–6. https://doi.org/10.1057/978-1-349-95121-5_2296-1

Morrison, T. K. (1977). The Effects of Population Size and Population Density on the Manufactured Exports of Developing Countries. *Southern Economic Journal, 43*(3), 1368. https://doi.org/10.2307/1057796

Ningrum, J. W., Khairunnisa, A. H., & Huda, N. (2020). Pengaruh Kemiskinan, Tingkat Pengangguran, Pertumbuhan Ekonomi dan Pengeluaran Pemerintah Terhadap Indeks Pembangunan Manusia (IPM) di Indonesia Tahun 2014-2018 dalam Perspektif Islam. *Jurnal Ilmiah Ekonomi Islam, 6*(2), 212. https://doi.org/10.29040/jiei.v6i2.1034

Nisak, S. C. (2016). Seemingly Unrelated Regression Approach for GSTARIMA Model to Forecast Rain Fall Data in Malang Southern Region Districts. *CAUCHY: Jurnal Matematika Murni Dan Aplikasi, 4*(2), 57–64. https://doi.org/10.18860/ca.v4i2.3488

Novriansyah, M. A. (2018). Pengaruh Pengangguran dan Kemiskinan Terhadap Pertumbuhan Ekonomi di Provinsi Gorontalo. *Gorontalo Development Review, 1*(1), 59. https://doi.org/10.32662/golder.v1i1.115

Pangesti, I., & Susanto, R. (2018). Pengaruh Inflasi terhadap Indeks Pembangunan Manusia (IPM) di Indonesia. *JABE (Journal of Applied Business and Economic), 5*(1), 70. https://doi.org/10.30998/jabe.v5i1.3164

Pramoedyo, H., Ashari, A., & Fadliana, A. (2020). Forecasting and Mapping Coffee Borer Beetle Attacks Using GSTAR-SUR Kriging and GSTARX-SUR Kriging Models. *ComTech: Computer, Mathematics and Engineering Applications, 11*(2), 65–73. https://doi.org/10.21512/comtech.v11i2.6389

Silitonga, D. (2021). Pengaruh Inflasi Terhadap Produk Domestik Bruto (PDB) Indonesia Pada Periode Tahun 2010-2020. *Esensi: Jurnal Manajemen Bisnis, 24*(1), 111-122. Retrieved from https://ibn.e-journal.id/index.php/ESENSI/article/view/231

Sukirno, S. (2008). *Mikroekonomi Teori Pengantar, (3rd Ed).* PT. RajaGrafind Persada. Jakarta.

Wafiq, A. N., & Suryanto, S. (2021). The Impact of Population Density and Economic Growth on Environmental Quality: Study in Indonesia. *Jurnal Ekonomi & Studi Pembangunan, 22*(2), 301–312. https://doi.org/10.18196/jesp.v22i2.10533

Wau, T. (2022). Economic Growth, Human Capital, Public Investment, and Poverty in Underdeveloped Regions in Indonesia. *Jurnal Ekonomi & Studi Pembangunan, 23*(2), 189-200. https://doi.org/10.18196/jesp.v23i2.15307

Xu, X., Šarić, Ž., Zhu, F., & Babić, D. (2018). Accident severity levels and traffic signs interactions in state roads: a seemingly unrelated regression model in unbalanced panel data approach. *Accident Analysis & Prevention, 120*, 122–129. https://doi.org/10.1016/j.aap.2018.07.037

Zellner, A. (1962). An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *Journal of the American Statistical Association, 57*(298), 348–368. https://doi.org/10.1080/01621459.1962.10480664