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Dr. Dyah Maya Nihayah, S.E., M.Si.

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1. CO_2 Emissions in Indonesia: The Role of Urbanization and Economy Activities towards Net Zero Carbon. Dipublikasin pada jurnal *Economies* 2022, 10, 72, Edisi April 2023, ISSN: 2227-7099**.**

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7	02-03-2023	Manuscript Resubmitted
8	03-03-2023	Mengirimkan revisi
9	16-03-2023	Final Proofreading sebelum publikasi (Within 24 hours)
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Judul	: CO2 Emissions in Indonesia: The Role of Urbanization and Economy Activities towards Net Zero Carbon
Jurnal	: *Economies*
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Nomor	:72
Tanggal publikasi	: 23 Maret 2023
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Penulis	: Dyah Maya Nihayah, Izza Mafruhah, Lukman Hakim, Suryanto

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Thank you very much for resubmitting the modified version of the following manuscript:

Manuscript ID: economies-1603206
Type of manuscript: Article
Title: Air Pollution in Indonesia: The Role of Urbanization and Economy Activities towards Net Zero Carbon
Authors: Dyah Maya Nihayah *, Izza Mafruhah, Lukman Hakim, Suryanto Suryanto
Received: 2 February 2022
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Authors: Dyah Maya Nihayah *, Izza Mafruhah, Lukman Hakim, Suryanto Suryanto

Received: 02 February 2022
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Title	CO_2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon
Journal	*Economies* (https://www.mdpi.com/journal/economies)
Volume	10
Issue	4
Abstract	This study aims to analyze the nexus between CO_2 emissions, urbanization, and economic activity, as well as identify whether the pollution haven hypothesis is proven in Indonesia. It utilized time series data of Indonesia during the 1971–2019 period. Furthermore, the vector error correction model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship with CO_2 emissions was observed from the model. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO_2 emissions in the short term. It was concluded that the achievement of the Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed, where all parties need to have the same vision towards net zero carbon.
Keywords	CO_2 emissions; economic activities; urbanization; net zero carbon

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Submission to Publication (Days)	48
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Editor Decision

Decision	Accept in current form
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Kang, H. CO_2 Emissions Embodied in International Trade and Economic Growth: Empirical Evidence for OECD and Non-OECD Countries. *Sustainability* **2021**, *13*, 12114. doi: 10.3390/su132112114 (https://doi.org/10.3390/su132112114)

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Authors: Dyah Maya Nihayah *, Izza Mafruhah, Lukman Hakim, Suryanto Suryanto
Received: 2 February 2022
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Dear Ms. Marijana Ilic

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Journal: Economies (https://www.mdpi.com/journal/economies) (ISSN 2227-7099)

Manuscript ID: economies-1603206

Type: Article

Title: CO2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon (https://www.mdpi.com/2227-7099/10/4/72)

Abstract: This study aims to analyze the nexus between air pollution, urbanization, and economic activity, as well as to identify whether the pollution haven hypothesis is proven in Indonesia. This also utilized the time series data of Indonesia during the 1971-2019 period. Furthermore, the Vector Error Correction Model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship in air pollution was observed from the model. Also, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to air pollution in the short term. It was concluded that the achievement of Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed where all parties need to have the same vision towards net zero carbon.

The coverletter for this review report has been saved in the database. You can safely close this window.

Authors' Responses to Reviewer's Comments (Reviewer 2)

Author's Notes:

Dear Reviewer 2

Enclosed, please find our response according to your comments and suggestions

Kind regard,

Author's Notes File: Report Notes (/user/review/displayFile/24578107/x2wOLIIe?file=author-coverletter&report=17699013)

Review Report Form

Quality of English Language
( ) English very difficult to understand/incomprehensible
( ) Extensive editing of English language and style required
( ) Moderate English changes required
(x) English language and style are fine/minor spell check required
( ) I am not qualified to assess the quality of English in this paper

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	(x)	( )	( )	( )
Is the research design appropriate?	(x)	( )	( )	( )
Are the methods adequately described?	( )	(x)	( )	( )
Are the results clearly presented?	( )	(x)	( )	( )
Are the conclusions supported by the results?	( )	(x)	( )	( )

Comments and Suggestions for Authors

Your manuscript focus on very extensive research on the assessment of the relationship between macroeconomic factors and air pollution. The research and manuscript itself are processed with a meticulous approach. This is a very actual and modern field of research. Despite that facts, I have some comments and recommendations on your manuscript.

Please specify which table:
Line. 247 "The first stage was the ADF unit root test, where the table showed that the variables......"

Table 2. Air pollution and carbon dioxide emission are not the same. I mean that emissions are not air pollution. Air pollution is a concentration of pollutants at a specific point. It will be very nice if you could better tittle this indicator.

The equations on page 8 are very difficult to read and understand, it will be very nice if you could provide a more detailed description of the statistical and mathematical apparatus and comments of the equations.

You developed a model of macroeconomic factors and evaluated what depends on it. In that case, it would be appropriate, not only to comment on the resulting macroeconomic model but also to visualize it in some suitable way using formulas, diagrams, graphs, etc. This should probably be added to the chapter in the results and discussion.

Despite these comments, I am satisfied with your manuscript in generally. Therefore I recommend acceptation of your manuscript after minor revisions.

Submission Date	02 February 2022
Date of this review	17 Feb 2022 23:16:07

REVIEWER 2

<u>Comments and Suggestions number 1</u> : Please specify which table:
Line. 247 "The first stage was the ADF unit root test, where the table showed that the variables......".

<u>Respond 1</u>:

Thank you for the correction. What is meant in line 247 is table 4. A correction has been made in the manuscript in line 283 (write by red ink).

<u>Comments and Suggestions number 2</u> : Table 2. Air pollution and carbon dioxide emission are not the same. I mean that emissions are not air pollution. Air pollution is a concentration of pollutants at a specific point. It will be very nice if you could better tittle this indicator.

<u>Respond 2:</u>

- Thank you for your comment. Actually, air pollution in my article refers to studies of Liang et al. (2019) and Ponce & Alvarado (2019). Finally, I received your suggestion to replace air pollution with CO2 emissions.
- I have adjusted the manuscript according to your suggestion (write by yellow highlight).

<u>Comments and Suggestions number 3:</u> The equations on page 8 are very difficult to read and understand, it will be very nice if you could provide a more detailed description of the statistical and mathematical apparatus and comments of the equations.

<u>Respond 3</u>:

Thank you very much for your advice. I have provided a more description of the empirical equation. The details can be seen below:

Therefore, the general model for the regression is shown as follows (Maparu & Mazumder, 2017):

$$y_t = \sum_{i=1}^{p} \beta_i y_{t-i} + \emptyset x_t + u_t \qquad 2$$

If the variables are cointegrated, Vector Error Correction Model (VECM) can be used instead of VAR. Equation 3 shows the general model for VECM.

$$\Delta y_t = \sum_{i=1}^{q} \beta_i y_{t-i} + \emptyset x_t + \gamma ECT_t + u_t$$

Where, Δ is the first difference operator, y_t = the vector of the non-stationary variable k I (1), x_t = the vector of the deterministic variable, β_i and ∅ = the parameters to be calculated, u_t = the white noise error terms, *p* and *q* = the maximum lag length

Vector Error Correction Model (VECM) can be made for testing Granger causality between the variables of CO2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment. The empirical equation of VECM is presented as follow:

$$\begin{bmatrix} \Delta \mathrm{LCO2}_t \\ \Delta \mathrm{UD}_t \\ \Delta \mathrm{LEG}_t \\ \Delta \mathrm{LX}_t \\ \Delta \mathrm{LM}_t \\ \Delta \mathrm{FDI}_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{j=1}^{L} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} & \beta_{35j} & \beta_{36j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} & \beta_{45j} & \beta_{46j} \\ \beta_{51j} & \beta_{52j} & \beta_{53j} & \beta_{54j} & \beta_{55j} & \beta_{56j} \\ \beta_{61j} & \beta_{62j} & \beta_{63j} & \beta_{64j} & \beta_{65j} & \beta_{66j} \end{bmatrix} \begin{bmatrix} \Delta \mathrm{LCO2}_{t-j} \\ \Delta \mathrm{UD}_{t-j} \\ \Delta \mathrm{LEG}_{t-j} \\ \Delta \mathrm{LX}_{t-j} \\ \Delta \mathrm{LM}_{t-j} \\ \Delta \mathrm{FDI}_{t-j} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} \mathrm{ECT}_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \quad (4)$$

Where α and γ are the coefficients to be estimated. ECT_{t-1} is the lagged residual term derived from the long-run relationship. If γ negative and significantly different from zero, it is a long-term interplay. L is the maximum lag length, Δ is the first difference operator dan ε is the error terms.

Recall equation 4, we can break it down into the following equations:

$$\Delta \mathrm{LCO2}_t = \alpha_1 + \sum_{j=1}^{L} \beta_{11j} \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{12j} \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{13j} \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{14j} \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{15j} \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{16j} \Delta \mathrm{FDI}_{t-j} + \gamma_1 \mathrm{ECT}_{t-1} + \varepsilon_{1t} \quad (5)$$

$$\Delta \mathrm{UD}_t = \alpha_2 + \sum_{j=1}^{L} \beta_{21j} \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{22j} \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{23j} \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{24j} \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{25j} \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{26j} \Delta \mathrm{FDI}_{t-j} + \gamma_2 \mathrm{ECT}_{t-1} + \varepsilon_{2t} \quad (6)$$

$$\Delta \text{LEG}_t = \alpha_3 + \sum_{j=1}^{L} \beta_{31j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{32j}\, \Delta \text{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{33j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{34j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{35j}\, \Delta \text{LM}_{t-j} + \sum_{j=1}^{L} \beta_{36j}\, \Delta \text{FDI}_{t-j} + \gamma_3 \text{ECT}_{t-1} + \varepsilon_{3t} \quad (7)$$

$$\text{LX}_t = \alpha_4 + \sum_{j=1}^{L} \beta_{41j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{42j}\, \Delta \text{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{43j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{44j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{45j}\, \Delta \text{LM}_{t-j} + \sum_{j=1}^{L} \beta_{46j}\, \Delta \text{FDI}_{t-j} + \gamma_4 \text{ECT}_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta \text{LM}_t = \alpha_5 + \sum_{j=1}^{L} \beta_{51j}\, \Delta \text{LM}_{t-j} + \sum_{j=1}^{L} \beta_{52j}\, \Delta \text{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{53j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{54j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{55j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{56j}\, \Delta \text{FDI}_{t-j} + \gamma_5 \text{ECT}_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \text{FDI}_t = \alpha_6 + \sum_{j=1}^{L} \beta_{61j}\, \Delta \text{FDI}_{t-j} + \sum_{j=1}^{L} \beta_{62j}\, \Delta \text{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{63j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{64j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{65j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{66j}\, \Delta \text{LM}_{t-j} + \gamma_6 \text{ECT}_{t-1} + \varepsilon_{6t} \quad (10)$$

The long-term equilibrium is shown by the negative ECT coefficient. It indicates a correction of the variable movement towards its long-term equilibrium, hence, the coefficient should be negative. This indicates the closer to zero of the coefficient values, the quicker the adjustment towards long-run equilibrium.

In the manuscript, I have revised it in lines 210-248 (write by red ink).

<u>Comments and Suggestions number 4</u>: You developed a model of macroeconomic factors and evaluated what depends on it. In that case, it would be appropriate, not only to comment on the resulting macroeconomic model but also to visualize it in some suitable way using formulas, diagrams, graphs, etc. This should probably be added to the chapter in the results and discussion.

<u>Respond 4</u>:

Thank you for the comment. I have made visualize it in graphs and make a related analysis, according to your suggestion. The addition is as below

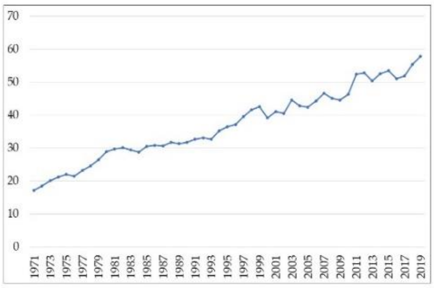

Figure 2. Time trend of CO2 Emissions

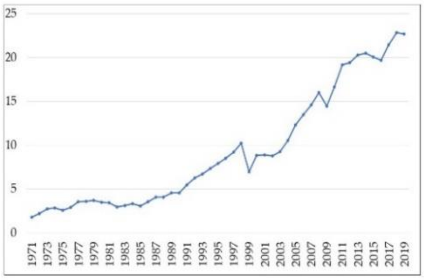

Figure 5. Time trend of Export

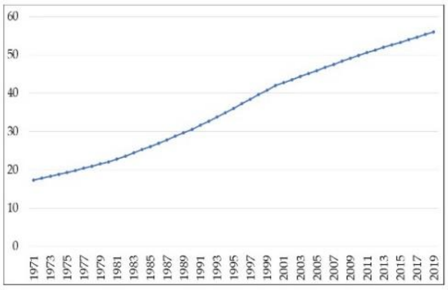

Figure 3. Time trend of Urbanization

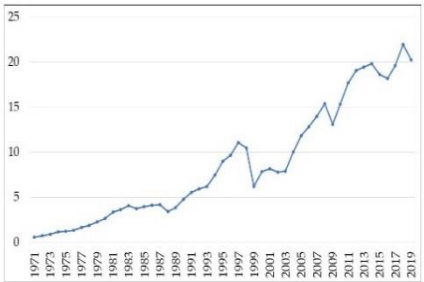

Figure 6. Time trend of Import

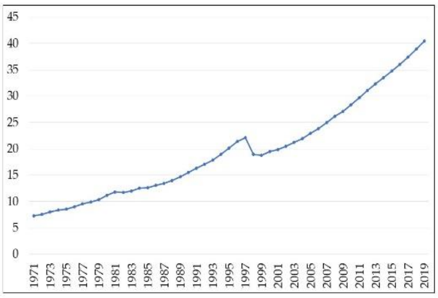

Figure 4. Time trend of Economic growth

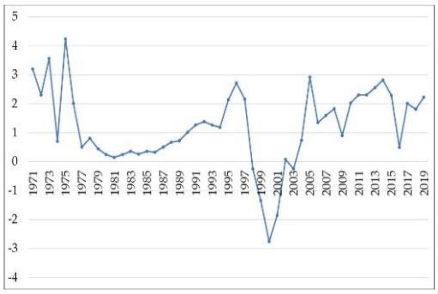

Figure 7. Time trend of Foreign Direct Investment

Figure 2 shows trends in CO2 emissions that have occurred since 1971, tend to increase. It implies that significant growth in emissions has occurred since 1971, accompanied by increasing urbanization and economic growth (Figure 3 and Figure 4). Prior to the economic crisis in 1998, an international agreement did not influence the reduction of CO2 emission in Indonesia. Carbon emission constantly raised up after the first United Nation Environmental Conference which was conducted in Stockholm in 1971. Since 1998, a significant increase in economic activities, such as exports and imports (Figure 5 and Figure 6), have been led to a relatively higher emission. The Kyoto Protocol, which was signed in 1997, made the trend of carbon emissions fluctuate, as well as a Paris Agreement in 2015. It implies that the influence of international agreement diplomacy on economic activities related to the reduction of CO2 emissions. Figure 6 shows the volatile of FDI net inflows. Since the heaviest economic crisis in 1998, foreign direct investment has tended to increase. Global shocks had brought it down in 2008 and 2016 but could rise again at the end of 2019. This confirm that the interest of investors to Indonesia is still high.

In the manuscript, I have added it in lines 251-268 (write by red ink).

Comments and Suggestions number 5: Despite these comments, I am satisfied with your manuscript in generally. Therefore I recommend acceptation of your manuscript after minor revisions.

Respond 5:

We are very grateful for the suggestions from all reviewers. Your suggestions, devices, and criticisms are very valuable to us. Hoping in the future, we will be better at writing articles.

Journal: Economies (https://www.mdpi.com/journal/economies) (ISSN 2227-7099)

Manuscript ID: economies-1603206

Type: Article

Title: CO2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon (https://www.mdpi.com/2227-7099/10/4/72)

Abstract: This study aims to analyze the nexus between air pollution, urbanization, and economic activity, as well as to identify whether the pollution haven hypothesis is proven in Indonesia. This also utilized the time series data of Indonesia during the 1971-2019 period. Furthermore, the Vector Error Correction Model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship in air pollution was observed from the model. Also, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to air pollution in the short term. It was concluded that the achievement of Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed where all parties need to have the same vision towards net zero carbon.

The coverletter for this review report has been saved in the database. You can safely close this window.

Authors' Responses to Reviewer's Comments (Reviewer 3)

Author's Notes: Dear Reviewer 3

Enclosed, please find our response according to your comments and suggestions

Kind regard,

Author's Notes File: Report Notes (/user/review/displayFile/24582695/1gLKBnIE?file=author-coverletter&report=17703022)

Reviewers Menu

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Review Report Form

Quality of English Language

( ) English very difficult to understand/incomprehensible
( ) Extensive editing of English language and style required
( ) Moderate English changes required
(x) English language and style are fine/minor spell check required
( ) I am not qualified to assess the quality of English in this paper

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	( )	(x)	( )	( )
Is the research design appropriate?	( )	( )	(x)	( )
Are the methods adequately described?	( )	( )	(x)	( )
Are the results clearly presented?	( )	( )	(x)	( )
Are the conclusions supported by the results?	( )	(x)	( )	( )

Comments and Suggestions for Authors

1. the terminology between air pollution and GHG emission should be clearly clarify. This is a bit confusing on this terms. this could mislead the reader's expectation. Title may be revised accordingly
2. in term of CO2, please also clarify whether this is only CO2 emission or CO2 eq emission?
3. The methodology should also be clearly stated the data needed and type of data, it should be included the data analyzed in this study not just a table consist of source of reference (include the value of the data used)
4. line 41-42: the economic performance increased by 0.1-0.28 points, but the air pollution decreased by more than 10%, a condition which will be a threat to air quality in Indonesia. please provide source (reference). what is air pollution and air quality in these terms ? how this statement related to CO2 emission being analysis in this study
5. 39-40 : consistency statement between GHG (CO2) and air pollution should be clarify

Submission Date 02 February 2022

Date of this review 20 Feb 2022 16:46:52

REVIEWER 3

<u>Comments and Suggestions number 1</u> : the terminology between air pollution and GHG emission should be clearly clarify. This is a bit confusing on this terms. this could mislead the reader's expectation. Title may be revised accordingly.

<u>Respond 1:</u>

- Thank you for your comment. Actually, air pollution in my article refers to studies of Liang et al. (2019); Ponce & Alvarado (2019). Finally, I received your suggestion to replace air pollution with CO2 (GHG) emissions.
- I have adjusted and revised the manuscript, as well as the title, according to your advice. (write by yellow highlight).

<u>Comments and Suggestions number 2 :</u> In term of CO2, please also clarify whether this is only CO2 emission or CO2 eq emission?

<u>Respond 2:</u>

Thank you for the question. I intend to clarify that the CO2 used in this research is CO2 emission. Its referred to the concept of CO2 emission from the World Bank. It stated that carbon dioxide emissions or CO2 emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring.

<u>Comments and Suggestions number 3:</u> The methodology should also be clearly stated the data needed and type of data, it should be included the data analyzed in this study not just a table consist of source of reference (include the value of the data used).

<u>Respond 3:</u>

Thank you very much for your critics in this section. I have completed the information in table 2 as follow:

Variable	Description	Unit	Source
CO2 emissions (CO2)	The residual CO2 that is discharged into the environment	Tonnes CO2/ Terajoule	International Energy Agency, 2021
Economic growth (GDPC)	Gross Domestic Product per capita	IDR in constant price	World Bank
Urbanization (UD)	The percentage of people living in urban areas.	%	World Bank

Export (X)	The value of exports made by a country.	IDR in constant price	World Bank
Import (M)	The value of imports of goods to a country.	IDR in constant price	World Bank
Foreign direct investment (FDI)	Net inflow as the proportion of total Gross Domestic Product	%	World Bank

Then, I have also added in table 3, the summary statistics for all variables used in this study.

Table 3. Summary of Descriptive Statistics

Variable	Maximum	Minimum	Mean	Std. Dev.	Observations
LCO2	1.762	1.235	1.549	0.136	49
UD	55.985	17.338	36.176	12.588	49
LEG	7.607	6.864	7.247	0.209	49
LX	15.359	14.258	14.852	0.328	49
LM	15.342	13.771	14.777	0.423	49
FDI	4.241	-2.757	1.198	1.335	49

I have adjusted the manuscript according to your suggestion (write by pink ink).

Comments and Suggestions number 4: line 41-42: the economic performance increased by 0.1-0.28 points, but the air pollution decreased by more than 10%, a condition which will be a threat to air quality in Indonesia. please provide source (reference). what is air pollution and air quality in these terms ? how this statement related to CO2 emission being analysis in this study

Respond 4: Thanks for the correction. First of all, I apologize for the typo in line 40. The term "air pollution" on line 40 should be "air quality". (write by pink ink).

In this study, air quality referred to the Regulations of the Ministry of Environment of the Republic of Indonesia (2020). It is stated that air quality can be determined from 5 main pollutant parameters, namely oxidant/ozone on the surface, particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide. Previously, in the Regulation of the State Minister for the Environment of the Republic of Indonesia Number 10, in 2012 also regulated the quality standards of exhaust gas emissions that are safe for the environment. Exhaust gas emissions including in this category are Hydrocarbons, CO Carbon Monoxide, Carbon Dioxide, Oxygen and Nitrogen Oxide compounds.

Comments and Suggestions number 5: 39-40 : consistency statement between GHG (CO2) and air pollution should be clarify

<u>Respond 5</u>: Thank you for your concern about the terminology of air pollution and CO2 (GHG) emissions. I have corrected the manuscript and replaced the term of air pollution with CO2 emissions. (write by yellow highlight).

Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>

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1 message

Economies Editorial Office <economies@mdpi.com> Wed, Mar 16, 2022 at 10:30 AM
Reply-To: info@sciprofiles.com, marijana.ilic@mdpi.com
To: Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>
Cc: Marijana Ilic <marijana.ilic@mdpi.com>

Dear Mrs. Nihayah,

Congratulations on your paper being accepted for publication in Economies.

To enhance your visibility, as well as that of co-authors, we would like to invite you to set up profiles on SciProfiles (https://sciprofiles.com), which will allow us to add a link for each author to their permanent homepage in the final version of the paper.

You can use the link below to register or login using your MDPI credentials:
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4. Please complete all sections of your profile in as detailed as possible, so that other researchers can find you.

Many thanks in advance for your collaboration. If you have any questions, please feel free to contact info@sciprofiles.com.

Kind regards,

Dr. Shu-Kun Lin, Founder and President
https://sciprofiles.com/profile/2

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Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>

[Economies] Manuscript ID: economies-1603206 - Option to Add ORCID to Your Manuscript

1 message

Economies Editorial Office <economies@mdpi.com> Wed, Mar 16, 2022 at 6:28 PM
Reply-To: Marijana Ilic <marijana.ilic@mdpi.com>, Economies Editorial Office <economies@mdpi.com>
To: Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>, Izza Mafruhah <izza_wisnu@yahoo.com>, Lukman Hakim <lukkim@gmail.com>
Cc: economies@mdpi.com

Dear Authors,

We have recently sent you a request for final proof-reading of economies-1603206. You now have the option to connect your ORCID to the paper via the following link:

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Best regards,
Ms. Marijana Ilic
Assistant Editor, MDPI Novi Sad
E-Mail: marijana.ilic@mdpi.com

MDPI Branch Office, Novi Sad
Bulevar Oslobođenja 83, 21000 Novi Sad, Serbia
Tel. +381 21 300 14 49

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Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>

[Economies] Manuscript ID: economies-1603206 - Final Proofreading Before Publication (Within 24 hours)

1 message

Economies Editorial Office <economies@mdpi.com> Wed, Mar 16, 2022 at 6:28 PM
Reply-To: marijana.ilic@mdpi.com
To: Dyah Maya Nihayah <dyah_maya@mail.unnes.ac.id>
Cc: Izza Mafruhah <izza_wisnu@yahoo.com>, Lukman Hakim <lukkim@gmail.com>, Suryanto Suryanto <suryanto_feb@staff.uns.ac.id>, Economies Editorial Office <economies@mdpi.com>, marijana.ilic@mdpi.com

Dear Mrs. Nihayah,

We invite you to proofread your manuscript to ensure that this is the final version that can be published and confirm that you will require no further changes from hereon:

Manuscript ID: economies-1603206
Type of manuscript: Article
Title: Air Pollution in Indonesia: The Role of Urbanization and Economy Activities towards Net Zero Carbon
Authors: Dyah Maya Nihayah *, Izza Mafruhah, Lukman Hakim, Suryanto Suryanto
Received: 2 February 2022
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CO^2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon

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Abstract: This study aims to analyze the nexus between CO^2 emissions, urbanization, and economic activity, as well as identify whether the pollution haven hypothesis is proven in Indonesia. It utilized time series data of Indonesia during the 1971–2019 period. Furthermore, the vector error correction model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship with CO^2 emissions was observed from the model. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short term. It was concluded that the achievement of the Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed, where all parties need to have the same vision towards net zero carbon.

Keywords: CO2 emissions; economic activities; urbanization; net zero carbon

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1. Introduction

The 2021 UN climate change conference (COP26) was held in Glasgow, Scotland, on 31 October–12 November 2021. This event is an extension of the Paris Agreement and serves as a reminder that a big agenda needs to be immediately carried out to address climate change due to human activities. Several countries are challenged with the trade-off between economic growth and environmental degradation. The environmental Kuznets curve (EKC) hypothesis explains an inverted U-shaped relationship between economic growth and environmental degradation. This means environmental pressure increases in the early stages of economic growth due to the increased release of pollutants as well as extensive and intensive exploitation of natural resources associated with greater use of production (Grossman and Krueger 1991; Özokcu and Özdemir 2017; Shahbaz et al. 2019; Rahman et al. 2020).

Also, it is found that the efforts to reach a turning point are challenging in terms of improving environmental quality. CO^2 emissions are increased when economic development activities are high. This indicates that the quicker the regional economic growth, the worse the air pollution (Hossain 2011; Ben Abdallah et al. 2013; Hasanov et al. 2018).

Before the pandemic, Indonesia was ranked as one of the world's emerging markets at the end of 2019. In fact, the economic growth has been reasonably consistent at about 5.1% in 2019 due to the strong trust of foreign investors. However, in 2015, Indonesia became the fourth-largest emitter of greenhouse gases, which is a major source of concern. According to the World Bank Indicators released in 2020, there was an increase in CO^2 emissions of 4.4%/year on average between 2001 and 2018. The highest increase and lowest decrease in the emissions occurred in 2011 and 2013 at 14.8% and 7.5%, respectively.

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Furthermore, the economic performance increased by 0.1–0.28 points, but the air quality decreased by more than 10%, a condition that will be a threat to Indonesia. According to the World Bank, about 220 million Indonesians will live in cities and towns by 2045. Consequently, the high population density will lead to accelerated economic activity in the region. This is in line with Liang et al. (2019), who stated that rapid urbanization will promote social and economic development but raise some environmental pollution problems (Camagni et al. 1998). This implies that environmental quality will deteriorate as more resources are used to promote economic activity.

COP26 provides momentum for the nation to prepare risk mitigation in international trade with the application of levies on carbon emissions. Empirical studies related to the influence of international trade in Indonesia showed different results. Bhattacharya et al. (2019) found that there was no significant effect between trade openness and CO^2 emissions. Meanwhile, Nathaniel (2020) stated that Indonesian trade can reduce natural CO^2 emissions in the short-term but exacerbate environmental degradation in the long-term. The open economic system has contributed to CO^2 emissions (F. Chen et al. 2021); therefore, this study focused more specifically on the relationship between exports and imports of CO^2emissions due to the carbon emission tax policy on international trade. In addition, it harbors suspicion about the two responses that are different from CO^2 emissions; hence, separate identification is needed to determine the final policy. Studies of exports and imports have provided different results. Exports promote an increase in emissions (Salehnia et al. 2020) and also improve environmental quality (Hasanov et al. 2018; Pié et al. 2018). The result of import activities showed that imports cause environmental degradation (Hasanov et al. 2018; Pié et al. 2018; Salehnia et al. 2020), while Aljawareen and Saddam (2017) stated that it is a stimulus for improving air quality.

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In advance, the existence of the pollution haven hypothesis needs to be tested. Salahuddin et al. (2019) used the link between trade openness induced by globalization to prove the pollution haven hypothesis. Meanwhile, this study examines whether foreign direct investment results in increased CO^2 emissions. The reinforcing reason is that Indonesia has great potential for foreign investment. According to the United Nations Conference on Trade and Development (UNCTAD), Indonesia is among the top 20 developing countries that were the destination for FDI globally in 2017 and 2018. Hence, the relationship between investment and the environment in these countries can be examined to prove the pollution haven hypothesis. Based on previous studies, there is a two-way relationship between FDI and CO^2 emissions (Tang and Tan 2015; Omri et al. 2014). The connection between CO^2 emissions and FDI will be beneficial to the environment when the pollution haven hypothesis is not discovered (Z. Chen et al. 2021). Meanwhile, Omri et al. (2014) stated that FDI had a unidirectional relationship and a positive effect on CO^2 emissions in Qatar. Kizilkaya (2017) discovered that foreign direct investment was ineffective on CO^2 emissions in Turkey. Therefore, this study aims to analyze the interplay of urbanization, economic growth, exports, imports, foreign direct investment, and CO^2 emissions. It also proves whether the pollution halo or haven hypotheses existed in Indonesia from 1971 to 2019. It is of prominent importance to developing countries or those highly dependent on international trade, related to the global commitment to reducing carbon emissions and the transition process toward a low-carbon country.

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The theoretical basis and previous empirical studies are presented after the background of the study to comprehend the relationship between urbanization, economic growth, export, import, foreign direct investment, and CO^2 emissions. Afterward, the methods section provides an overview of the variables used, and the stages carried out. The next section presents the results, which are subsequently deepened by the discussion, as well as the conclusions and policy implications.

2. Literature Review

The relationship between urbanization and environmental quality is founded on the concept of an urban area in which demand-driven activities center on cost reduction. This is due to its closeness to other regions with similar proximity, endowment resources, and high population density. In addition, because of this association, people are able to rationally relocate to urban areas. Urbanization is formed through socio-economic development. According to Pernia et al. (1983), population growth is often higher in rural areas than urban areas. This indicates that there is a direct demographic effect, which involves reducing the proportion of urban areas. It was also stated that population growth hampers economic development. This indicates that urbanization is either influenced directly or indirectly by socio-economic development, through population growth. Meanwhile, Firebaugh (1979) stated that it is influenced directly and indirectly by the deterioration of rural conditions and economic development, as well as previous urbanization, respectively. Hence, urbanization theory should consider the conditions in rural and urban areas because it is applied to both developed and developing countries.

The migration of people to urban areas is carried out through different phases of the urbanization process as follows (Sarungu 2001). Firstly, there is agrarian urbanization, which entails innovation in agricultural technology application and leads to an increase in assertive productivity. Secondly, there is urbanization in industrialized metropolitan areas. It is characterized by an increasing concentration of population and economic activity in the vicinity of major cities, as well as substantial infrastructure investment to facilitate efficient export and import operations (Turok and McGranahan 2013). Thirdly, in a growing metropolitan area, there is a postindustrial non-metropolitan counter urbanization, which is characterized by a reduction in the population's physical and socioeconomic capacity.

The findings of empirical studies showed different results. Urbanization and pollution have bidirectional causality (Santillán-Salgado et al. 2020; Nosheen et al. 2020; Salahuddin et al. 2019; Amin et al. 2020; Abbasi et al. 2020;), while there is a one-way causality between urbanization and CO^2 (Ponce and Alvarado 2019; Bashir et al. 2021). Specifically, several empirical studies were conducted to determine the process that occurs in post-industrial non-metropolitan counter-urbanization. Urban regions, road area per capita, and GDP were found to have negative effects on CO^2 emissions (Qiu et al. 2019). Therefore, it needs to be controlled with careful planning and mitigation of CO^2 emissions (Yang et al. 2015; Hassan et al. 2020) because emissions and urbanization have a relationship (Santillán-Salgado et al. 2020).

Previous studies showed an inverted U-shaped relationship between economic growth and environmental degradation which is in line with the environmental Kuznets curve (EKC) hypothesis (Borhan et al. 2012; Lin and Zhu 2018; Hanif 2018; Tang and Tan 2015; dan C. H. Wang et al. 2019). An initial study by Grossman and Krueger (1991) and Tanger et al. (2011) reported the inverse relationship between CO^2 emissions and economic growth. The interesting outcome was presented by Hossain (2011) and Hossain (2012), which stated that several literatures had failed to establish an inverse U relationship with the real-life data. Particularly in developed and developing countries, the studies that examined the causal relationship between energy consumption and growth produced three different results. Other studies reportedly discovered two-way causation, as well as unidirectional causes and causality direction from output growth to energy consumption.

Economists also conducted studies on the relationship between FDI and economic growth. Externalities were transferred from industrialized to developing countries, based on the assumption that FDI is an important asset to boost greater development. According to developing countries, the investment served as a means of transferring factors, due to the accelerating pace of general purpose technologies (GPT), while introducing advanced technology and science. This means the countries exploited these factors as assets to increase economic growth. Furthermore, FDI defines economic openness from a financial standpoint, which has been proven to promote economic growth, although this has not been shown in the United States (Omri et al. 2015). The consequence of this openness is the emergence of negative externalities. The pollution haven hypothesis was developed from the studies of Copeland and Taylor (1994) and Chen et al. (2021). Based on this hypothesis, three dimensions (Aliyu 2005) were observed. Firstly, heavily polluting enterprises relocated from industrialized to developing countries, where strict environmental regulations were not enforced. Global free trade, on the other hand, has increased industrial and polluting activities by relocating to nations with weak environmental policies. Secondly, the transfer of hazardous waste from developed to developing countries (industrial production and nuclear energy). This issue was also the subject of the Basle Convention on hazardous waste. Thirdly, multinational companies involved in the production of petroleum and its products, as well as lumber and other forest resources, including the extraction of non-renewable natural resources in developing countries without control. These factors are related to conscious environmental policy decisions and how they impact the environment, production, and future trade. However, the pollution haven hypothesis has two empirical consequences, namely (1) FDI outflows in developed countries are positively correlated with environmental policy tightening, and (2) Pollution in developing countries is positively correlated with the inflows of FDI. The existence of foreign investment brings technological efficiency compared to those within the country (Balogh and Jámbor 2017; Adams et al. 2020; dan Salehnia et al. 2020). In addition, Aljawareen and Saddam (2017) showed that FDI had a positive interplay with CO^2 emissions in Qatar. The selected studies about the pattern of CO^2 emissions, urbanization, and economic activities are summarized in Table 1.

Table 1. Literature review of pattern of CO2 emissions, urbanization, and economic activities.

Authors	Country/Region (Periods)	Technique Analysis	Findings
	Economy Growth and CO^2 emissions		
Rahman et al. (2020)	5 South Asian Countries (1990–2017)	Granger causality, VECM FMOLS, DOLS, generalized method of moments (GMM)	ECO^2 + EG EG ↔ ECO^2
C. H. Wang et al. (2019)	5 Countries: Germany, Italy, India, Taiwan and Japan (1950–2010)	*Rolling regression*	EG ∩ ECO^2
Vo et al. (2019)	ASEAN 5 (1971–2014)	Granger causality, FMOLS, DOLS	EG → ECO^2
Abbasi et al. (2020)	8 Asia Countries (1982–2017)	Granger causality.	EG ≠ E$CO^2$2
Chikaraishi et al. (2015)	140 Countries (1980–2008)	Laten STIRPAT model	EG − ECO^2
(Batool et al. (2021)	ASEAN 5 (1980–2018)	Granger causality, VECM	EG + ECO^2 EG ≠ ECO^2 (Ind, Mal) LR: EG ↔ ECO^2 (Ind, Tha) SR: EG → ECO^2 (Phi, Sgp)
Joshua et al. (2020)	South Africa	ARDL	EG + ECO^2 EG → ECO^2
Phong et al. (2018)	Vietnam (1985–2015)	ARDL	EG + ECO^2
Bashir et al. (2019)	Indonesia (1985–2017)	VECM	EG ≠ ECO^2,
	Urbanization and CO^2 emissions		
Salahuddin et al. (2019)	South Africa (1980–2017)	Unit root tests (Zivot and Andrews single, dan Bai dan Perron), cointegration, ARDL	U ↔ ECO^2
Al-Mulali et al. (2013)	MENA Countries (1980–2009)	Pedroni's cointegration, panel Granger causality	U ↔ ECO^2 U + ECO^2
Hanif (2018)	34 Countries in Africa (1995–2015)	System generalized method of moment (GMM)	U + ECO^2
Adedoyin and Bekun (2020)	7 Countries (1995–2014)	Panel VAR approach, FMOLS, pooled mean group–ARDL	U ↔ ECO^2

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H. S. Ali et al. (2017)	Singapore (1970–2015)	ARDL	U – ECO_2
R. Ali et al. (2019)	Pakistan (1972–2014)	ARDL, VECM	U + ECO_2 U → ECO_2
Bekhet and Othman (2017)	Malaysia (1971–2015)	VECM, Granger causality	LR: U ↔ ECO_2 , Inv. Domestic ↔ E CO_2 SR: U → E CO_2, U → EG, Inv. Domestic → EG
Martínez-Zarzoso and Maruotti (2011)	Developing countries (1975–2003)	LSDVC, GMM methods	U ∩ ECO_2
Akorede and Afroz (2020)	Nigeria (1970–2017)	Causality tests, ARDL	U – ECO_2
Lin and Zhu (2018)	282 Cities in China (2012)	Bayesian model average	U – ECO_2
Ergas et al. (2016)	USA (2002–2007)	*A hybrid panel model*	U – ECO_2
Borhan et al. (2012)	8 East Asia	Simultaneous equation	ECO_2-U
Dong et al. (2019)	14 Countries maju	Two fixed-effect panel threshold models	SR: U ≠ECO_2 Middle Run : U – ECO_2
Economic Activities and CO_2 emissions			
Kizilkaya (2017)	Turkey (1970–2014)	ARDL	FDI ≠ ECO_2
Tang and Tan (2015)	Vietnam (1976–2009)	Cointegration, Granger causality	FDI ↔ ECO_2
Hasanov et al. (2018)	Azerbaijan, Bahrain, Kuwait, Oman, Qatar, Russia, Saudi Arabia, United Arab Emirates (UAE) and Venezuela (1995–2013)	PDOLS, PFMOLS, PMG methods, panel ECM	X – ECO_2 M + ECO_2
Aljawareen and Saddam (2017)	6 GCC Countries (1998–2008)	Panel data	FDI + ECO_2 (Qatar) M – ECO_2 (KSA)
Omri et al. (2014)	54 Countries (1990–2011)	Dynamic simultaneous equation method, GMM Arellano and Bond.	FDI ↔ ECO_2
Amin et al. (2020)	13 Asian (1985–2019)	Cointegration tests, FMOLS., Panel VECM	TO ↔ ECO_2 U + ECO_2, TO + ECO_2 U ↔ ECO_2
Anwar et al. (2020)	East Asia (1980–2017)	Panel data	U + ECO_2 TO + ECO_2
S. P. Nathaniel (2020)	Indonesia (1971–2014)	ARDL	U + ECO_2 LR: TO + ECO_2 SR: TO – ECO_2
Omri et al. (2015)	12 MENA countries (1990–2011)	Generalized method of moments (GMM)	TO→ ECO_2
S. Nathaniel and Khan (2020)	ASEAN (1990–2016)	Unit root tests, ointegration.	EG→TO
Adams et al. (2020)	19 Countries Sub-Saharan Africa (1980–2011)	Estimator IV-GMM	FDI- ECO_2
Ahmed et al. (2017)	ASEAN 8 (1985–2015)	Panel unit root tests, Panel cointegration test, Forecast: Innovative Accounting Approach (IAA)	EG → TO
Chandran and Tang (2013)	ASEAN 5 (1971–2008)	Cointegration, Granger causality	FDI ≠ ECO_2 FDI ↔ ECO_2 (Tha, Mal)
Pié et al. (2018)	30 Countries (1992–2012)	Bayesian framework	X – ECO_2 M + ECO_2

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Akalpler and Hove (2019)	India (1971–2014)	ARDL	$ECO^2 \rightarrow X$ $M \rightarrow ECO^2$ M → EG (-) M → EG (+)
Salehnia et al. (2020)	14 MENA Countries (2004–2016)	Panel quantile regression	FDI – ECO^2 TO + ECO^2 M + ECO^2 X + ECO^2
Al-Mulali and Sheau-Ting (2014)	189 Countries (1990–2011)	Panel fully modified OLS (FMOLS)	TO + ECO^2
F. Chen et al. (2021)	64 Countries (2001–2019)	Panel quantile regression	TO + ECO^2

Remark: ECO^2: CO^2 emissions, U: urbanization, EG: economic growth, X: export, M: import, FDI: foreign direct investment, TO: trade openness. SR are LR are short-run and long-run, respectively. "+" and "−" indicate positive and negative effect, respectively. "→" "↔" and "≠" indicate unidirectional, bidirectional, and independence relationships, respectively. "∩" indicates shaped U curve.

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3. Methodology

This study was conducted using a descriptive quantitative method. The data were obtained from the International Energy Agency in 2021 and the World Development Indicators (WDI) that were published by the World Bank in 2021. Furthermore, time series data were obtained from 1971 to 2019. This period was selected based on the consideration that the first UN Environmental Conference was conducted in Stockholm in 1971. The variables description is presented in Table 2.

Table 2. Variables Description.

Variable	Description	Unit	Source
CO^2 emissions (CO^2)	The residual CO2 that is discharged into the environment	Tonnes CO2/Terajoule	International Energy Agency, 2021
Economic growth (GDPC)	Gross Domestic Product per capita	IDR in constant price	World Bank
Urbanization (UD)	The percentage of people living in urban areas.	%	World Bank
Export (X)	The value of exports made by a country.	IDR in constant price	World Bank
Import (M)	The value of imports of goods to a country.	IDR in constant price	World Bank
Foreign direct investment (FDI)	Net inflow as the proportion of total Gross Domestic Product	%	World Bank

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Besides urbanization and foreign direct investment, which is taken as the proportion of total GDP, all variables are expressed in the form of logarithms to minimize the effect of heteroscedasticity (Maparu and Mazumder 2017). Table 3 shows a summary of the descriptive statistics of variables.

Table 3. Descriptive Statistics.

Variable	Maximum	Minimum	Mean	Std. Dev.	Observations
LCO^2	1.762	1.235	1.549	0.136	49
UD	55.985	17.338	36.176	12.588	49
LEG	7.607	6.864	7.247	0.209	49
LX	15.359	14.258	14.852	0.328	49

LM	15.342	13.771	14.777	0.423	49
FDI	4.241	−2.757	1.198	1.335	49

In this study, the analysis was conducted in different stages (Figure 1).

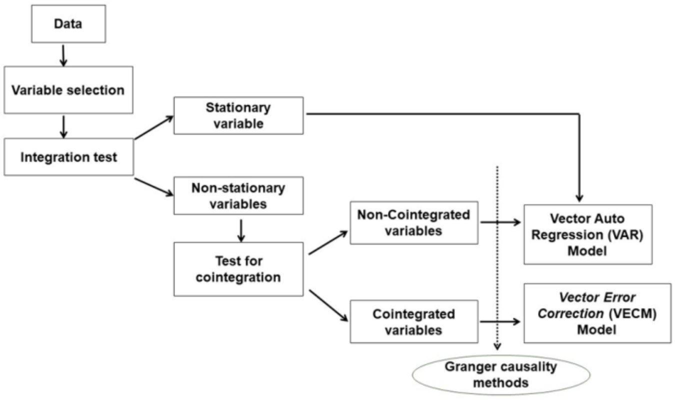

Figure 1. Test Stages in Granger Causality.

The first step is to use a preliminary statistical test to verify stationarities for all variables. This is conducted through the usual unit root method, which is known as the augmented Dickey–Fuller test (ADF). This step is important for two reasons: (1) The causality test is highly sensitive to serial stationarity, and (2) most of the time-series data for macroeconomic indicators are non-stationary. The ADF test is very popular for testing sequence integration of variables. Empirically, Equation (1) is represented as follows:

$$\Delta y_t = x_t b + \delta y_{t-1} + \sum_{i=1}^{m} a_1 \Delta y_{t-1} + \varepsilon_t \quad (1)$$

where y_t = time series to be tested, x_t = the selected exogenous regressor that contained constants and trends, a and b = the parameters that should be estimated, ε_t = the white noise error terms, m = the maximum lag length determined using Schwarz information and Akaike information criteria (SIC and AIC), and Δ = delta. According to the second step, when both series were integrated from the same order, the lag length was determined through the AIC and SIC, with the presence of cointegration also checked. Furthermore, the null hypothesis (H0: δ = 0) was tested against the alternative (Ha: δ < 0). When the null hypothesis is true, the existence of a unit root is confirmed, with the series observed as non-stationary. However, when the null hypothesis is rejected, stationary series are indicated.

Based on this study, the cointegration test was carried out through the Johansen method by focusing on the statistical value of the trace and maximum Eigen analysis value. The vector error correction model (VECM) is used when variables are co-integrated. However, when not co-integrated, the vector auto regression (VAR) model is used. Therefore, the general model for the regression is shown as follows (Maparu and Mazumder 2017):

$$y_t = \sum_{i=1}^{p} \beta_i y_{t-i} + \gamma x_t + u_t \quad (2)$$

where, y_t = the vector of the non-stationary variable k I (1), x_t = the vector of the deterministic variable, β_i and γ = the parameters to be calculated, u_t = the innovation vector, and p = the VAR sequence.

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According to the Granger causality test for equation (2), a variable (x) was stated to be a Granger causal to the other (y). This was observed when the lagging value of x increased the predictability of y, provided that other data were present. Moreover, the bivariate causality was divided into 3 categories, as follows: (1) Unidirectional: This causality was direct from x to y, when the coefficient on lagged x_t was significantly different from zero as a group. It was also directed from x to y, when y_t is the dependent variable and the coefficient on lagged y_t does not differ significantly from zero. The causality was also directed from x to y when x_t is the dependent variable. (2) Bidirectional: This indicated a relationship between x and y when the coefficient on the lagged x_t significantly differed from zero as a group. Moreover, it indicated a relationship, when y_t is the dependent variable. The coefficient on lagged y_t was significantly different from zero, when x_t is the dependent variable. (3) Independence: The causality occurred when the coefficients on x_t and y_t lagged were significantly different from zero in both equations.

If the variables are cointegrated, the vector error correction model (VECM) can be used instead of VAR. Equation (3) shows the general model for VECM.

$$\Delta y_t = \sum_{i=1}^{q} \beta_i y_{t-i} + \emptyset x_t + \gamma ECT_t + u_t \quad (3)$$

where, Δ is the first difference operator, β_i and $\emptyset$ = the parameters to be calculated, u_t = the white noise error terms, and q = the maximum lag length.

The vector error correction model (VECM) can be used for testing Granger causality between the variables of CO^2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment. The empirical equation of VECM is presented as follow:

$$\begin{bmatrix} \Delta LCO^2_t \\ \Delta UD_t \\ \Delta LEG_t \\ \Delta LX_t \\ \Delta LM_t \\ \Delta FDI_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{j=1}^{L} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} & \beta_{35j} & \beta_{36j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} & \beta_{45j} & \beta_{46j} \\ \beta_{51j} & \beta_{52j} & \beta_{53j} & \beta_{54j} & \beta_{55j} & \beta_{56j} \\ \beta_{61j} & \beta_{62j} & \beta_{63j} & \beta_{64j} & \beta_{65j} & \beta_{66j} \end{bmatrix} \begin{bmatrix} \Delta LCO^2_{t-j} \\ \Delta UD_{t-j} \\ \Delta LEG_{t-j} \\ \Delta LX_{t-j} \\ \Delta LM_{t-j} \\ \Delta FDI_{t-j} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \quad (4)$$

where α and γ are the coefficients to be estimated and ECT_{t-1} is the lagged residual term derived from the long-run relationship. If γ is negative and significantly different from zero, it is a long-term interplay. L is the maximum lag length, Δ is the first difference operator, and ε is the error term.

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Recall Equation (4). We can break it down into the following equations:

$$\Delta LCO^2_t = \alpha_1 + \sum_{j=1}^{L} \beta_{11j}\, \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{12j}\, \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{13j}\, \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{14j}\, \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{15j}\, \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{16j}\, \Delta FDI_{t-j} + \gamma_1 ECT_{t-1} + \varepsilon_{1t} \quad (5)$$

$$\Delta UD_t = \alpha_2 + \sum_{j=1}^{L} \beta_{21j}\, \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{22j}\, \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{23j}\, \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{24j}\, \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{25j}\, \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{26j}\, \Delta FDI_{t-j} + \gamma_2 ECT_{t-1} + \varepsilon_{2t} \quad (6)$$

$$\Delta LEG_t = \alpha_3 + \sum_{j=1}^{L} \beta_{31j}\, \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{32j}\, \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{33j}\, \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{34j}\, \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{35j}\, \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{36j}\, \Delta FDI_{t-j} + \gamma_3 ECT_{t-1} + \varepsilon_{3t} \quad (7)$$

$$\Delta LX_t = \alpha_4 + \sum_{j=1}^{L} \beta_{41j}\, \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{42j}\, \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{43j}\, \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{44j}\, \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{45j}\, \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{46j}\, \Delta FDI_{t-j} + \gamma_4 ECT_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta \mathrm{LM}_t = \alpha_5 + \sum_{j=1}^{L} \beta_{51j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{52j}\, \Delta \mathrm{LCO^2}_{t-j} + \sum_{j=1}^{L} \beta_{53j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{54j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{55j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{56j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_5 \mathrm{ECT}_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \mathrm{FDI}_t = \alpha_6 + \sum_{j=1}^{L} \beta_{61j}\, \Delta \mathrm{FDI}_{t-j} + \sum_{j=1}^{L} \beta_{62j}\, \Delta \mathrm{LCO^2}_{t-j} + \sum_{j=1}^{L} \beta_{63j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{64j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{65j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{66j}\, \Delta \mathrm{LM}_{t-j} + \gamma_6 \mathrm{ECT}_{t-1} + \varepsilon_{6t} \quad (10)$$

The long-term equilibrium is shown by the negative ECT coefficient. It indicates a correction of the variable movement towards its long-term equilibrium; hence, the coefficient should be negative. This indicates that the closer to zero the coefficient values are, the quicker the adjustment towards long-run equilibrium.

4. Results and Discussion

4.1. Empirical Results

Before examining cointegration between variables, we present an overview related to CO^2 emissions in Indonesia during the period 1971–2019. This is necessary to find out its role towards net zero emissions through the vector error correction model.

Figure 2 shows trends in CO^2 emissions that have occurred since 1971, tending to increase. It implies that significant growth in emissions has occurred since 1971, accompanied by increasing urbanization and economic growth (Figures 3 and 4). Prior to the economic crisis in 1998, an international agreement did not influence the reduction of CO^2 emissions in Indonesia. Carbon emissions constantly rose after the first United Nations Environmental Conference, which was conducted in Stockholm in 1971. Since 1998, a significant increase in economic activities, such as exports and imports (Figures 5 and 6), have led to relatively higher emissions. The Kyoto Protocol, which was signed in 1997, made the trend of carbon emissions fluctuate, as well as the Paris Agreement in 2015. It implies the influence of international agreement diplomacy on economic activities related to the reduction of CO^2 emissions. Figure 7 shows the volatility of FDI net inflows. Since the heaviest economic crisis in 1998, foreign direct investment has tended to increase. Global shocks had brought it down in 2008 and 2016, but it rose again at the end of 2019. This confirms that the interest of investors in Indonesia is still high.

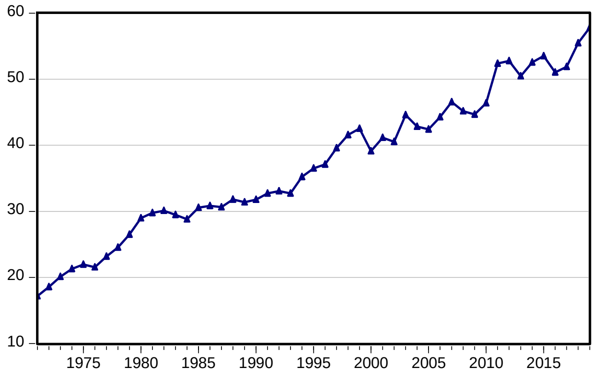

Figure 2. Time trend of CO^2 Emissions.

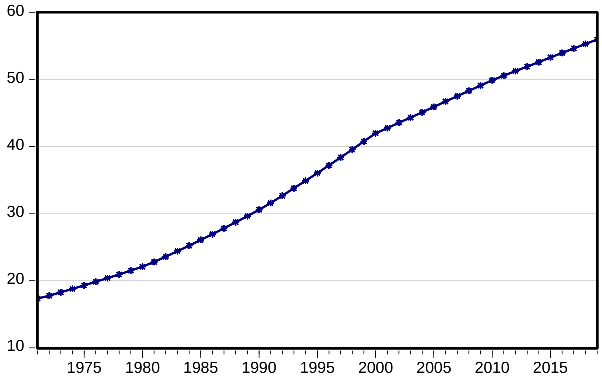

Figure 3. Time trend of Urbanization.

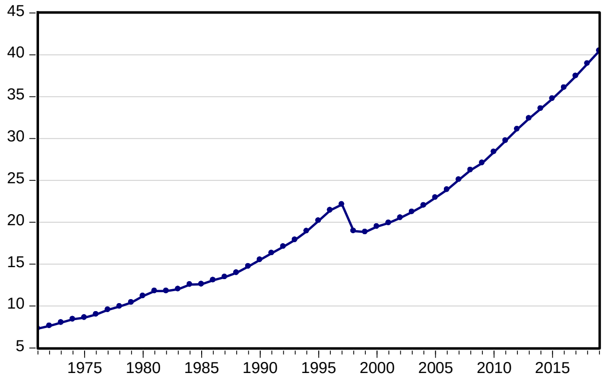

Figure 4. Time trend of Economic growth.

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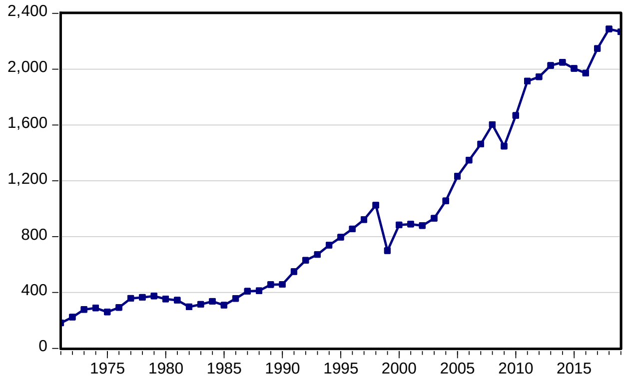

Figure 5. Time trend of Export.

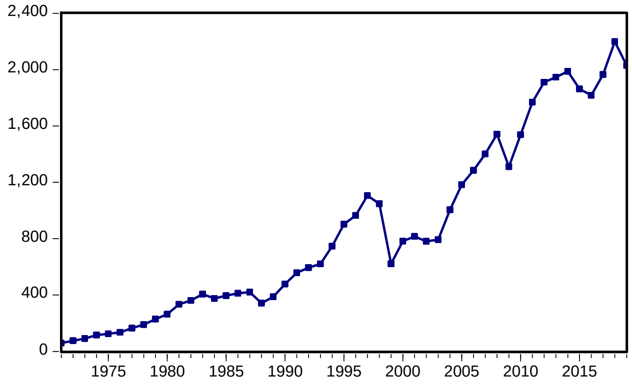

Figure 6. Time trend of Import.

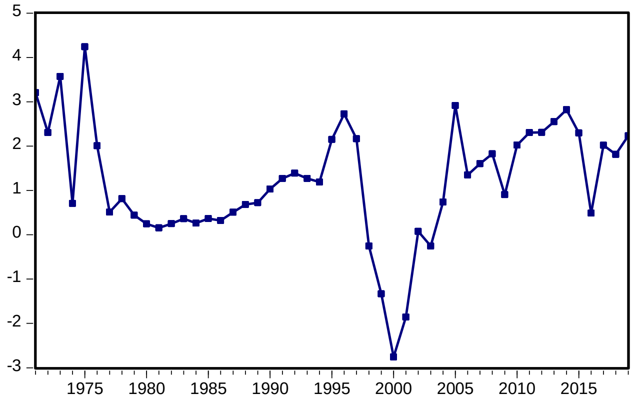

Figure 7. Time trend of Foreign Direct Investment.

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The dynamic causal relationship between CO^2 emissions, urbanization, economic growth, export, and import activities, as well as foreign direct investment, was assessed through several steps. Firstly, each variable containing the unit root was checked. Secondly, the test to determine whether there was a long-term cointegration relationship between the variables was conducted. Thirdly, the estimation of the VECM to deduce the Granger causal relationship between the variables was carried out. A summary of the results is shown in Table 4 based on the first stage, which is the unit root identification of each variable.

Table 4. Root Test of ADF-PP.

Variable	ADF		PP	
	t-Statistic	**Prob.**	**t-Statistic**	**Prob.**
Level				
LCO^2	−1.802599	0.3748	−2.454673	0.1329
UD	−1.697425	0.4258	0.198221	0.9697
LEG	−0.618192	0.8566	−0.606277	0.8593
LX	−0.630870	0.8536	−0.601572	0.8603
LM	−2.536889	0.1135	−2.592632	0.1016
FDI	−3.296863	0.0206	−3.348542	0.0181
First difference				
L CO^2	−5.806780	0.0000 *	−7.190028	0.0000 *
UD	−1.579417	0.4848	−1.648529	0.4502
LEG	−5.103162	0.0001 *	−5.072025	0.0001 *
LX	−8.107578	0.0000 *	−8.160933	0.0000 *
LM	−6.087550	0.0000 *	−6.087550	0.0000 *
FDI	−9.123195	0.0000 *	−9.067042	0.0000 *
Second difference				
UD	−6.02711	0.0000 *	−5.980405	0.0000 *

Remarks: * significant at the 1% level.

The first stage was the ADF unit root test, which showed that the variables of CO^2 emissions, urbanization, economic growth, exports, imports, and foreign investment were not stationary in the level integration analysis (Table 4). Furthermore, the first difference was conducted on all stationary variables I (1), except for the UD. This indicated that there was a difference in the level of stationarity within the UD variable, as the Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), Fisher–ADF, and Fisher–PP tests were carried out, respectively. The summary of the results is shown in Table 5. Based on the use of the Levin–Lin–Chu, Pesaran–Shin, and ADF–PP methods, the first difference root test showed that all results were stationary at I (1), due to the probability which was less than 5%. This also confirmed that the variables of CO^2 emissions, urbanization, economic growth, exports, imports, and foreign investment, were tested for cointegration.

Table 5. Group Unit Root Test.

Method	Level		First Different	
	Statistic	**Prob.**	**Statistic**	**Prob.**
Levin, Lin & Chu t *	−0.23198	0.4083	−7.51263	0.0000 *
Im, Pesaran and Shin W-stat	−0.50251	0.3077	−12.0491	0.0000 *
ADF-Fisher Chi-square	15.9249	0.1947	133.866	0.0000 *
PP-Fisher Chi-square	15.4927	0.2156	135.685	0.0000 *

Remarks: * significant at the 1% level. Number of observations 276.

The optimal lag length was determined based on the Akaike information criterion (AIC). According to the determination of the most optimal lag, the highest LR and low AIC, HQIC, and SBIC values were observed. The results showed the optimal lag length used was two, through the consideration of the lowest AIC value. Subsequently, a stability test was conducted to determine the usable model (VAR or VECM). The results also showed the variables to be used met the stability criteria, as the modulus values were less than one; hence, the VAR or VECM was used.

After passing the stability analysis, the cointegration test was conducted. Furthermore, the Johansen cointegration test was found to be based on the linear determinism assumption (intercept and trend). A long-term balance was observed when the trace or Max-Eigen values were more than the critical value of 5%. Therefore, the results of the Johansen cointegration test based on Trace and Max-Eigen statistics are summarized in Table 6.

Table 6. Johansen Cointegration Test.

Hypothesis	**Eigenvalue**	**Trace-Test**		**Max-Eigen Test**	
		Statistic	***ρ* Value**	**Statistic**	***ρ* Value**
None	0.731063	136.8953	0.0000 *	60.41077	0.0001 *
At most 1	0.504075	76.48456	0.0133 **	32.26119	0.0770
At most 2	0.361128	44.22337	0.1054	20.61038	0.3004
At most 3	0.242559	23.61299	0.2173	12.77925	0.4727
At most 4	0.159968	10.83374	0.2219	8.018521	0.3768
At most 5	0.059365	2.815217	0.0934	2.815217	0.0934

Remark: * Significant at the 1% level; ** Significant at the 5% level.

The null hypothesis of Johansen's test stated that cointegration occurred when at least one analysis was cointegrated. The null hypothesis was accepted based on the results, which showed trace and Max-Eigen test values of two and one cointegrations at the 0.05 level, respectively. This indicated that there was cointegration between variables, as CO^2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment, had a long-term relationship within the period of 1971 to 2019 in Indonesia. These variables were also eligible for the VEC framework.

Based on the use of VECM, the causality source was identified from the significance test that was conducted for the coefficient of the independent variable. According to the short-term causality, the Granger causality/block exogeneity Wald tests were used to determine the nullity of the parameters associated with the independent variable in each VECM equation, through the $\chi2$-Wald statistic. However, causality in the long term was tested by the significance of the adjustment speed. The t-statistic of the ECT coefficient that showed a long-term causal effect was also used.

Table 7 shows three out of six vectors had a negative value of ECT-1, but only Equation (5) was statistically significant at a 1% significance degree. This means only CO^2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurs from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short-term. Likewise, imports into urbanization and economic growth had a one-way relationship to exports and imports (Table 7).

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Table 7. Granger Causality/Block Exogeneity Wald Tests.

Dependent Variable	Short Run						Long Run	
	ΔL(CO_2)	ΔUD	ΔL(EG)	ΔL(X)	ΔL(M)	ΔFDI	Coefficient	*t*-Test
ΔL(CO_2)	-	18.72401 (0.0001) *	6.126103 (0.0467) **	1.802927 (0.406)	10.50891 (0.0052) *	31.76471 (0.000) *	−0.863939	−7.31613 *
ΔUD	0.885313 (0.6423)	-	0.894056 (0.6395)	1.505821 (0.471)	9.9198 (0.007) *	0.759596 (0.684)	0.62141	1.15879
ΔL(EG)	0.020633 (0.9897)	3.397833 (0.1829)	-	0.255068 (0.8803)	0.241267 (0.8864)	1.068797 (0.586)	−0.126233	−0.80081
ΔL(X)	2.835755 (0.2422)	2.549941 (0.2794)	16.40749 (0.0003) *	-	0.363593 (0.8338)	0.042006 (0.9792)	0.518394	1.31906
ΔL(M)	2.0033835 (0.3673)	1.69154 (0.4292)	30.15772 (0.0000) *	2.537506 (0.2812)	-	0.027722 (0.9862)	−0.017462	−0.03758
ΔFDI	2.94009 (0.2299)	4.537871 (0.1034)	2.024757 (0.3634)	1.783195 (0.4100)	3.849635 (0.1459)	-	11.73753	1.06675

Remark: * Significant at the 1% level; ** Significant at the 5% level; *** Significant at the 10% level.

4.2. Impulse Response

Impulse response CO_2 emissions to urbanization showed that the urban density was included in the counter-urbanization phase in the short-term. This phase is characterized by a decrease in the environmental, physical, and socio-economic carrying capacity of the population in the larger metropolitan area (Sarungu, 2001). The high level of urbanization can result in rapid population growth that leads to agglomeration and will be followed by efforts of people to fulfill their needs. Due to the speed and scale of escalation in these cities, they can induce great pressure on the environment and pose environmental degradation or threats to sustainable development (Cohen 2006). This result is in line with Agung PS et al. (2017) and Liang et al. (2019). In the long-term, CO_2 emissions will decrease along with the awareness of city dwellers about the importance of health and quality of life. This is consistent with the negative response of CO_2 emissions to urban density (Figure 8b). Therefore, urbanization can be directed to reduce CO_2 emissions by using the potential spillover of technology and high levels of education. This is consistent with Liu and Liu (2019), Hassan et al. (2020), and S. Wang et al. (2020).

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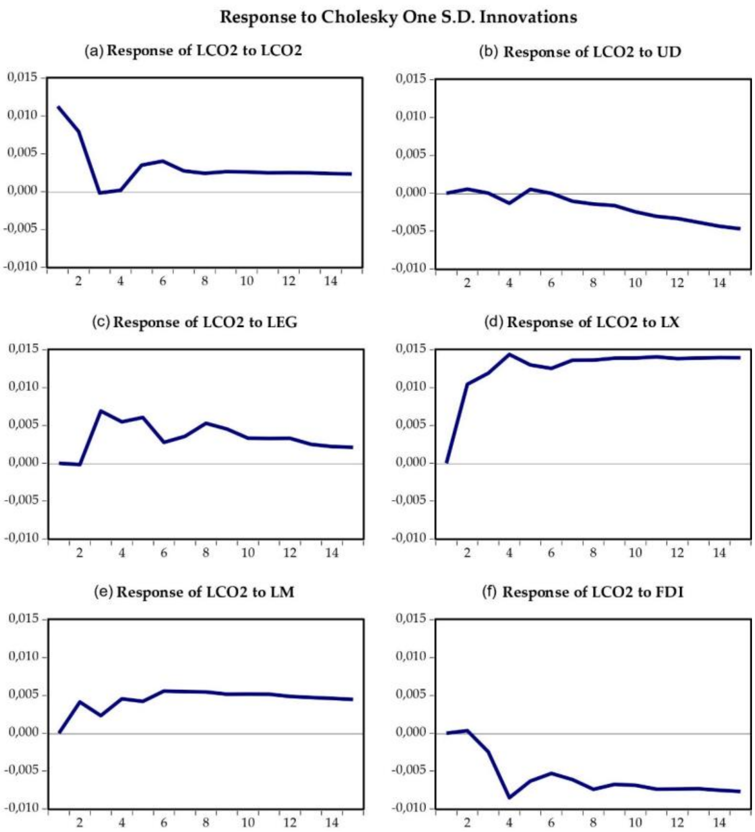

Figure 8. Impulse response functions.

Assuming FDI changes, the response of CO^{2} emissions was positive in the short run, but was negative in the third year, reaching its lowest point in the fourth year, and subsequently tends to move steadily (Figure 8f). The positive response of CO^{2} emissions during the shock in FDI was consistent with the VECM estimation in this study. It also showed an increase in FDI in the long run, leading to environmentally oriented investment. This is in line with Adams et al. (2020), Salehnia et al. (2020), and Chen et al. (2021). This is a great target that developing countries should build upon in order to realize the halo pollution hypothesis, along with the increasing FDI values every year. The responses of CO^{2} emissions to export and import economic activities were positive. A shock to exports will increase CO^{2} emissions sharply until the fourth year, and subsequently the changes tend to be stable in the long term (Figure 8d). The same pattern was shown by imports. Although the response to CO^{2} emissions was smaller than the shock to exports, it was also positive to changes in imports (Figure 8e). This is a formidable challenge for net-zero carbon. Actually, the policy of goods or commodities received from the rest of the world for Indonesian consumption has led to the procurement of cordial environmental commodities which minimizes the occurrence of CO^{2} emissions. The Government of Indonesia issued Statute Law Number 32 (UU No 32) in 2009 concerning Environmental Protection and Management (UU PPLH) as well as Statute Law Number 18 (UU No 18) in 2008

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concerning Waste Management (UU Waste Management). It was subsequently strengthened by the stipulation of Statute Law Number 7 (UU No 7) in 2014 concerning Trade, specifically Article 50 paragraph (1) and (2) which states that all goods can be exported or imported, except those prohibited, restricted, or otherwise stipulated by law. The newest implementation is regulated in Government Regulation No. 22 (PP No 22) in 2021 concerning the implementation of environmental protection and management. The climate change emergency at COP26 is time-bound, making net zero carbon policy mandatory for companies. Based on the results of variance decomposition (Table 8), the largest contribution to emissions comes from export activities. Therefore, failure to immediately adapt to a net zero carbon policy can lead to loss of global market share.

4.3. Variance Decomposition

Initially, the largest contribution to CO^2 emissions in the short term is the variance in the variable itself, but its contribution decreased afterward. The largest contribution was taken over by exports. Initially, it contributed only 34%, but increased continuously to become the largest at the end of the period (Table 8). Economic growth, FDI, urbanization, and imports also showed an increasing trend of contributions.

Table 8. Variance Decomposition of L CO^2.

Period	S.E.	Illustrated by Variable (%)					
		LCO^2	UD	LEG	LX	LM	FDI
1	0.01126	100	0	0	0	0	0
2	0.01778	60.0086	0.08991	0.00916	34.4567	5.39887	0.03685
3	0.02273	36.7204	0.05502	9.20014	48.4918	4.34863	1.18405
4	0.02912	22.3715	0.24277	9.14684	53.8769	5.08307	9.27894
5	0.03352	17.9672	0.20705	10.1653	55.6899	5.41679	10.5537
6	0.03693	15.9996	0.17066	8.9383	57.3913	6.7383	10.7619
7	0.04047	13.7793	0.21075	8.2149	59.0947	7.45419	11.2462
8	0.04409	11.9095	0.28457	8.34995	59.3394	7.81342	12.3031
9	0.04731	10.6518	0.36451	8.16321	60.1271	7.9719	12.7215
10	0.05029	9.69206	0.56157	7.65746	60.8523	8.11226	13.1244
11	0.05324	8.86569	0.83062	7.21289	61.2709	8.17552	13.6444
12	0.05596	8.22208	1.10796	6.87468	61.5566	8.15348	14.0852
13	0.05855	7.68971	1.4459	6.46236	61.8715	8.09846	14.4321
14	0.06108	7.21843	1.83961	6.06841	62.0817	8.00712	14.7847
15	0.06353	6.80859	2.24968	5.71815	62.1948	7.8946	15.1342

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The biggest contribution from export activities to CO^2 emissions should be the main notice related to Indonesia's commitment to achieving net-zero carbon by 2070. It should also be noted that international agreements to reduce CO^2 emissions were more or less efficient, but on the other hand, it has reduced the competitiveness and exports of several countries (C. H. Wang et al. 2019). Some countries in Asia, Europe, and America have implemented climate change mitigation programs to reduce emissions, which influences trading regulations. Requirements are set to the product; hence, it can be accepted globally by fulfilling sustainability requirements. For example, low-emission industrial product companies do not carry out deportations or execute forest conservation policies.

Foreign direct investment contributes to economic growth (Omri et al. 2014). It recognizes that investment, advanced technology, and knowledge can be transferred from industrialized countries to developing countries as an important asset to increase economic growth (Raz et al. 2012). Therefore, FDI can accelerate the speed of general purpose technologies (GPT) as the engine of growth. However, in some countries, the existence of this investment turns out to provide negative externalities to the environment, thereby proving the pollution haven hypothesis (Aliyu 2005; Aljawareen and Saddam 2017). The results showed foreign direct investment contributed significantly to CO^2 emissions. Economic agents should anticipate such factors carefully in order to remain competitive in

the global economy due to climate change. For example, the European Union makes policies regarding sanitary and phytosanitary goods to protect human and animal health, as well as environmental requirements (sustainable forest certificates and ecolabels, origin of products) for wood commodities. Other requirements, such as health and safety (free of fluorocarbon and formaldehyde emissions) and expensive costs are also not hard to manage. These should be borne by Indonesian entrepreneurs. Similarly, the Japanese government has a standard for wood products (Japan Agricultural Standard, JAS) and other export destination countries. Therefore, the right strategy is needed to synergize between economic growth air quality. Although economic activities should be carried out, it needs to be balanced in order to achieve net zero carbon.

5. Conclusions

This study aims to analyze the pattern of urbanization, economic growth, exports, imports, foreign direct investment, and CO^2 emissions. It also proved whether the halo or haven pollution hypotheses existed in Indonesia from 1971 to 2019. According to the results, CO^2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short term. Likewise, imports into urbanization and economic growth indicated a one-way relationship to exports and imports. This consequently strengthened the IPAL model by Dietz and Rosa (1997), which stated that population, income, and technology are considered as the main drivers of environmental impact.

The pollution haven hypothesis exists in Indonesia, and FDI had a one-way interplay with CO^2 emissions. The government should regulate air pollution by conditioning urbanization to be environmentally friendly through building several green open spaces and public transportation that uses accommodative fuel or renewable energy. Gradually, capital should be directed to investments that promote the economy to thrive. Foreign investment is used as a pillar to support the realization of a green urban development model. This is achieved by limiting negative environmental externalities through procurement and physical investment, particularly in power generation, transportation, and manufacturing industries.

Countries that are committed to climate change prevention in the Paris Agreement should compile long-term development plans that are integrated with strategies to reduce the amount of greenhouse gas emissions. In other words, the target for reducing emissions in its implementation needs to be coherent with several existing policies, specifically Indonesia's ambition to escape from the middle-income trap. The toughest challenge for the country is the use of coal energy sources. The transfer of coal plants to renewable energy in 2040 requires the support of international cooperation, technology, economic feasibility, and international funding to assist the energy transition. Therefore, the formation of a healthy and prosperous state ecosystem can be achieved when there is collaboration from all economic agents.

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Received: 2 February 2022
E-mails: dyah_maya@mail.unnes.ac.id, izza_wisnu@yahoo.com, lukkim@gmail.com, suryanto_feb@staff.uns.ac.id

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CO2 Emissions in Indonesia: The Role of Urbanization and Economy Activities towards Net Zero Carbon

Abstract: This study aims to analyze the nexus between CO2 emissions, urbanization, and economic activity, as well as to identify whether the pollution haven hypothesis is proven in Indonesia. This also utilized the time series data of Indonesia during the 1971-2019 period. Furthermore, the Vector Error Correction Model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship in CO2 emissions was observed from the model. Also, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO2 emissions in the short term. It was concluded that the achievement of Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed where all parties need to have the same vision towards net zero carbon.

Keywords: CO2 emissions, economic activities, urbanization, net zero carbon

1. Introduction

The 2021 UN climate change conference (COP26) was held in Glasgow, Scotland on 31 October–12 November 2021. This event is an extension of the Paris Agreement and as a reminder that a big agenda needs to be immediately carried out to address climate change due to human activities. Several countries are challenged with the trade-off between economic growth and environmental degradation. The Environmental Kuznets Curve (EKC) hypothesis explains an inverted U-shaped relationship between economic growth and environmental degradation. This means environmental pressure increases in the early stages of economic growth due to the increased release of pollutants as well as extensive and intensive exploitation of natural resources associated with greater use of production (Grossman & Krueger, 1991; Özokcu & Özdemir, 2017; Shahbaz et al., 2019; Rahman et al., 2020).

Also, it is found that the efforts to reach a turning point are challenging in terms of improving environmental quality. CO2 emission is increased when economic development activities are high. This indicates the quicker the regional economic growth, the worse the air pollution (Hossain, 2011; Ben Abdallah et al., 2013; Hasanov et al., 2018).

Before the pandemic, Indonesia was ranked as one of the world's emerging markets at the end of 2019. In fact, the economic growth has been reasonably consistent at about 5.1% in 2019 due to the strong trust of foreign investors. However, in 2015, Indonesia became the fourth-largest emitter of greenhouse gases, which is a major source of concern. According to the World Bank Indicators released in 2020, there was an increase in CO2 emissions by 4.4%/year on an average between 2001 and 2018. The highest increase and lowest decrease of the emission occurred in 2011 and 2013 at 14.8% and 7.5%, respectively. Furthermore, the economic performance increased by 0.1-0.28 points, but the air quality decreased by more than 10%, a condition that will be a threat in Indonesia. According to the world bank, about 220 million Indonesians will live in cities and towns by 2045. Consequently, the high population density will lead to accelerated economic activity in the region. This is in line with Liang et al. (2019)) which stated that rapid urbanization will promote social and economic development, but raise some environmental pollution problems (Camagni et al., 1998). This implies that environmental quality will deteriorate as more resources are used to promote economic activity.

COP26 is a momentum for the nation to prepare the risk mitigation in international trade with the existence of levies on carbon emissions. Empirical studies related to the influence of international trade in Indonesia showed different results. Ahmed et al. (2019) found that there was no significant effect between trade openness and CO2 emissions. Meanwhile, Nathaniel S.P. (2020) stated that Indonesian trade can reduce natural CO2 emissions in the short-term but exacerbate environmental degradation in the long-term. The open economic system has contributed to CO2 emissions, therefore, this study focused more specifically on the relationship between exports and imports of CO2 emissions due to the carbon emission tax policy on international trade. Also, it had suspicion on the two responses which are different from CO2 emissions, hence, separate identification is needed to determine the final policy. The studies of exports and imports have provided different results. Exports promote increase in emissions (Salehnia et al., 2020), and also improve environmental quality (Hasanov et al. 2018); Pié et al. 2018). The result of import activities showed imports cause environmental degradation (Hasanov et al., 2018; Pié et al., 2018; Salehnia et al., 2020), while Aljawareen (2017) stated that it is a stimulus for improving air quality.

In advance, the existence of pollution haven hypothesis needs to be tested. Salahuddin et al. (2019) used the link between trade openness induced by globalization to prove the pollution haven hypothesis. Meanwhile, this study examined whether foreign direct investment results in increased CO2 emissions. The reinforcing reason is that Indonesia has great potentials for foreign investment. According to the United Nations Conference on Trade and Development (UNCTAD), Indonesia is among the top 20 developing countries that are the destination for FDI globally in 2017 and 2018. Hence, the relation between investment and the environment in these countries is an action to prove the pollution haven hypothesis. Based on previous studies, there is a two-way relationship between FDI and CO2 emissions (Tang & Tan, 2015; Omri et al., 2014). The connection between CO2 emissions and FDI will be beneficial to the environment when the pollution haven hypothesis is not discovered (Z. Chen et al., 2021). Meanwhile, Omri et al. (2014) stated that FDI had a unidirectional relationship and a positive effect on CO2 emissions in Qatar. Kizilkaya (2017) discovered that foreign direct investment was ineffective on CO2 emissions in Turkey. Therefore, this study aims to analyze the interplay of urbanization, economic growth, export, import, foreign direct investment, and CO2 emissions. It also proved whether the pollution halo or haven hypotheses exist in Indonesia from 1971 to 2019. It is prominent to developing countries or those highly dependent on international trade, related to global commitment for reducing carbon emissions and having the transition process toward a low-carbon country.

The theoretical basic and previous empirical studies were presented after the background of the study to comprehend the relationship between urbanization, economic growth, export, import, foreign direct investment, and CO2 emissions. Afterward, the method provided an overview of the variables used, and the stages being carried out. The next section presented the results, which were subsequently deepened by discussions, as well as conclusions and policy implications.

2. Literature Review

The relationship between urbanization and environmental quality was founded on the concept of an urban area, in which demand-driven activities centered on cost reduction. This was due to its closeness to other regions with similar proximity, endowment resources, and high population density. Also, because of this association, people were able to rationally relocate to urban areas. Urbanization is formed through socio-economic development. According to Pernia et al. (1983), population growth was often higher in the rural area than urban. This indicated that there was a direct demographic effect, which involved reducing the proportion of urban areas. It was also stated that population growth hampered economic development. This indicated that urbanization was either influenced directly or indirectly by socio-economic development, through population growth. Meanwhile, Firebaugh (1979) stated that it was influenced directly and indirectly by the deterioration of rural conditions and economic development, as well as previous urbanization, respectively. Hence, urbanization theory should consider the conditions in rural and urban areas because it is applied to both developed and developing countries.

The migration of people to urban areas was carried out through different phases of the urbanization process as follows (Sarungu, 2001). Firstly, there is agrarian urbanization, which entails innovation in agricultural technology application and will lead to an increase in assertive productivity. Secondly, there is urbanization in industrialized metropolitan areas. It is characterized by an increasing concentration of population and economic activity in the vicinity of major cities, as well as substantial infrastructure investment to facilitate efficient export and import operations (Turok & McGranahan, 2013). Thirdly, in a growing metropolitan area, there is a postindustrial non-metropolitan counter urbanization, which is characterized by a reduction in the population's physical and socioeconomic capacity.

The findings of empirical studies showed different results. Urbanization and pollution had bidirectional causality (Santillán-Salgado et al., 2020; Nosheen et al., 2020; Salahuddin et al., 2019; Amin et al., 2020; Abbasi et al., 2020;), while there was a one-way causality between urbanization and CO2 (Ponce & Alvarado, 2019; Bashir et al., 2021). Specifically, several empirical studies were conducted to determine the process that occurred in the post-industrial non-metropolitan counter urbanization. The urban regions, road area per capita, and GDP were found to have negative effects on CO2 emissions (Qiu et al., 2019). Therefore, it needs to be controlled with careful planning and mitigation of CO2 emissions (Yang et al., 2015; Hassan et al., 2020) because the emissions and urbanization have a relationship (Santillán-Salgado et al., 2020).

Table 1. Literature review of pattern CO2 emissions, urbanization, and economic activities.

Authors	**Country/Region (periods)**	**Technique Analysis**	**Findings**
	Economy Growth and CO2 emissions		
Rahman et al. (2020)	5 South Asian Countries (1990-2017)	Granger causality, VECM FMOLS, DOLS, Generalized method of moments (GMM)	ECO2 + EG EG ↔ ECO2
C. H. Wang et al. (2019)	5 Countries: Jerman, Italy, India, Taiwan and Japan (1950–2010)	*Rolling regression*	EG ∩ ECO2
Vo et al. (2019)	ASEAN 5 (1971–2014)	Granger causality, FMOLS, DOLS	EG → ECO2
Abbasi et al. (2020)	8 Asia Countries (1982 – 2017)	Granger Causality.	EG ≠ ECO2
Chikaraishi et al. (2015)	140 Countries (1980 – 2008)	Laten STIRPAT Model	EG - ECO2
(Batool et al. (2021)	ASEAN 5 (1980-2018)	Granger Causality, VECM	EG + ECO2 EG ≠ ECO2 (Ind, Mal) LR : EG ↔ ECO2(Ind, Tha) SR : EG → ECO2 (Phi, Sgp)
Joshua et al. (2020)	Africa Selatan	ARDL	EG + ECO2 EG → ECO2
Phong et al. (2018)	Vietnam (1985 – 2015)	ARDL	EG + ECO2
Bashir et al. (2019)	Indonesia (1985-2017)	VECM	EG ≠ ECO2,
	Urbanization and CO2 emissions		

Salahuddin et al. (2019)	South Africa (1980–2017)	Unit root tests (Zivot & Andrews single, dan Bai dan Perron), Cointegration, ARDL	U ↔ ECO2
Al-Mulali et al. (2013)	MENA Countries (1980-2009)	Pedroni's Cointegration, Panel Granger causality	U ↔ ECO2 U + ECO2
Hanif (2018)	34 Countries in Africa (1995 - 2015)	Sistem generalized method of moment (GMM)	U + ECO2
Adedoyin & Bekun (2020)	7 Countries (1995- 2014)	Panel VAR approach, FMOLS, Pooled mean group–ARDL	U ↔ ECO2
H. S. Ali et al. (2017)	Singapura (1970 - 2015)	ARDL	U - ECO2
R. Ali et al. (2019)	Pakistan (1972-2014)	ARDL, VECM	U + ECO2 U → ECO2
Bekhet & Othman (2017)	Malaysia (1971–2015)	VECM, Granger causality	LR : U ↔ ECO2 , Inv. Domestic ↔ ECO2 SR : U → ECO2, U → EG, Inv. Domestic → EG
Martínez-Zarzoso & Maruotti (2011)	Developing countries (1975-2003)	LSDVC, GMM Methods	U ∩ ECO2
Akorede & Afroz, (2020)	Nigeria (1970-2017)	Causality tests, ARDL	U - ECO2
Lin & Zhu (2018)	282 Cities in China (2012)	Bayesian Model Average	U - ECO2
Ergas et al. (2016)	USA (2002 – 2007)	*A hybrid panel model*	U - ECO2
Borhan et al. (2012)	8 East Asia	Simultaneous equation	ECO2 - U
Dong et al. (2019)	14 Countries maju	Two fixed-effect panel threshold models	SR : U ≠ ECO2 Middle Run : U - ECO2
Economic Activities and CO2 emissions			
Kizilkaya (2017)	Turkey (1970-2014)	ARDL	FDI ≠ ECO2
Tang & Tan (2015)	Vietnam (1976-2009)	Cointegration, Granger Causality	FDI ↔ ECO2
Hasanov et al. (2018)	Azerbaijan, Bahrain, Kuwait, Oman, Qatar, Russia, Saudi Arabia, United Arab Emirates (UAE) and Venezuela (1995-2013)	PDOLS, PFMOLS, PMG methods, Panel ECM	X - ECO2 M + ECO2
Aljawareen (2017)	6 GCC Countries (1998-2008)	Panel data	FDI + ECO2 (Qatar) M - ECO2 (KSA)
Omri et al. (2014)	54 Countries (1990-2011)	Dynamic simultaneous equation method, GMM Arellano and Bond.	FDI ↔ ECO2
Amin et al. (2020)	13 Asian (1985–2019)	Cointegration tests, FMOLS., Panel VECM	TO ↔ ECO2 U + ECO2, TO + ECO2 U ↔ ECO2
Anwar et al. (2020)	East Asia (1980- 2017)	Panel data	U + ECO2 TO + ECO2
S. P. Nathaniel (2020)	Indonesia (1971–2014)	ARDL	U + ECO2 LR : TO + ECO2 SR : TO - ECO2
Omri et al. (2015)	12 MENA countries (1990-2011)	Generalized Method of Moments (GMM)	TO → ECO2
S. Nathaniel & Khan (2020)	ASEAN (1990-2016)	Unit root tests, Cointegration.	EG → TO

Adams et al. (2020)	19 Countries Africa Sub Sahara (1980-2011)	Estimator IV-GMM	FDI - ECO2
Ahmed et al. (2017)	ASEAN 8 (1985-2015)	Panel unit root tests, Panel cointegration test, Forecast: Innovative Accounting Approach (IAA)	EG → TO
Chandran & Tang (2013)	ASEAN 5 (1971-2008)	Cointegration, Granger Causality	FDI ≠ ECO2 FDI ↔ ECO2 (Tha, Mal)
Pié et al. (2018)	30 Countries (1992- 2012)	Bayesian framework	X- ECO2 M + ECO2
Akalpler & Hove (2019)	India (1971-2014)	ARDL	ECO2→ X M → ECO2 M → EG (-) M→ EG (+)
Salehnia et al. (2020)	14 MENA Countries (2004-2016)	Panel quantile regression	FDI - ECO2 TO + ECO2 M + ECO2 X + ECO2
Al-Mulali & Sheau-Ting (2014)	189 Countries (1990-2011)	Panel Fully Modified OLS (FMOLS)	TO + ECO2
F. Chen et al. (2021)	64 Countries (2001–2019)	Panel quantile regression	TO + ECO2

Remark: ECO2: CO2 emissions, U: urbanization, EG: Economic growth, X: export, M: import, FDI: foreign direct investment, TO: Trade Openness
SR are LR are short-run and long-run, respectively.
"+" and "-" indicate positive and negative effect, respectively.
"→" "↔" and "≠" indicate unidirectional, bidirectional, and independence relationships, respectively.
"∩" indicates shaped U curve.

Previous studies showed an inverted U-shaped relationship between economic growth and environmental degradation which is in line with the Environmental Kuznets Curve (EKC) hypothesis (Borhan et al., 2012; Lin & Zhu, 2018; Hanif 2018; Tang & Tan 2015, dan C. H. Wang et al., 2019). An initial study by Grossman and Krueger (1991) and Tanger et al. (2011) reported the inverse relationship between CO2 emissions and economic growth. The interesting outcome was presented by Hossain (2011) and Hossain (2012)which stated that several literatures failed to establish an inverse U relationship with the real-life data. Particularly in developed and developing countries, the studies that examined the causal relationship between energy consumption and growth produced 3 different results. Other studies reportedly discovered two-way causation, as well as unidirectional causes and causality direction, from output growth to energy consumption.

Economists also conducted studies on the relationship between FDI and economic growth. Externalities were transferred from industrialized to developing countries, based on the assumption that FDI is an important asset to boost greater development. According to developing countries, the investment served as a means of transferring factors, due to the accelerating pace of General-Purpose Technologies (GPT), while introducing advanced technology and science. This means the countries exploited these factors as assets to increase economic growth. Furthermore, FDI defines economic openness from a financial standpoint, which has proven to promote economic growth, although this has not been shown in the United States (Omri et al., 2015). The consequence of this openness is the emergence of negative externalities. The pollution haven hypothesis was developed from the studies of Copeland & Taylor (1994) and Chen et al. (2021). Based on this hypothesis, 3 dimensions (Aliyu, 2005)were observed. Firstly, heavily polluting enterprises relocated from industrialized to developing countries, where strict environmental regulations were not enforced. Global free trade, on the other hand, has increased industrial and polluting activities by relocating to nations with weak environmental policies. Secondly, the transfer of hazardous waste from developed to developing countries (industrial production and nuclear energy). This issue was also the subject of the Basle Convention on hazardous waste. Thirdly, multinational companies involved in the production of petroleum and its products, as well as lumber and other forest resources include extracting non-renewable natural resources in developing countries without control. These factors are related to conscious environmental policy decisions and how they impact the environment, production, and future trade. However, the pollution haven hypothesis has two empirical consequences, namely (1) FDI outflows in developed countries are positively correlated with environmental policy tightening, and (2) Pollution in developing countries is positively correlated with the inflows of FDI. The existence of foreign investment brings technological efficiency compared to those within the country (Balogh & Jámbor, 2017; Adams et al., 2020; dan Salehnia et al., 2020). In addition, Aljawareen (2017) showed that FDI had positive interplay with CO_2 emissions in Qatar. The selected studies about pattern of CO_2 emissions, urbanization, and economic activities are summarized in Table 1.

3. Methodology

This study was conducted using descriptive quantitative method. The data were obtained from the International Energy Agency in 2021 and the World Development Indicators (WDI) which was published by the World Bank 2021. Furthermore, time series data were obtained from 1971 to 2019. This period was selected based on the consideration that the first UN Environmental Conference was conducted in Stockholm in 1971. The variables description is presented in Table 2.

Table 2. Variables Description.

Variable	Description	Unit	Source
CO_2 emissions (CO_2)	The residual CO_2 that is discharged into the environment	Tonnes CO_2/ Terajoule	International Energy Agency, 2021
Economic growth (GDPC)	Gross Domestic Product per capita	IDR in constant price	World Bank
Urbanization (UD)	The percentage of people living in urban areas.	%	World Bank
Export (X)	The value of exports made by a country.	IDR in constant price	World Bank
Import (M)	The value of imports of goods to a country.	IDR in constant price	World Bank
Foreign direct investment (FDI)	Net inflow as the proportion of total Gross Domestic Product	%	World Bank

Besides urbanization and foreign direct investment, which is taken as the proportion of total GDP, all variables are expressed in the form of logarithms to minimize the effect of heteroscedasticity (Maparu & Mazumder, 2017). Table 3. shows the summary of descriptive statistics of variables.

Table 3. Descriptive Statistics.

Variable	Maximum	Minimum	Mean	Std. Dev.	Observations
LCO2	1.762	1.235	1.549	0.136	49
UD	55.985	17.338	36.176	12.588	49
LEG	7.607	6.864	7.247	0.209	49
LX	15.359	14.258	14.852	0.328	49
LM	15.342	13.771	14.777	0.423	49
FDI	4.241	-2.757	1.198	1.335	49

In this study, the analysis was conducted in different stages (Figure 1).

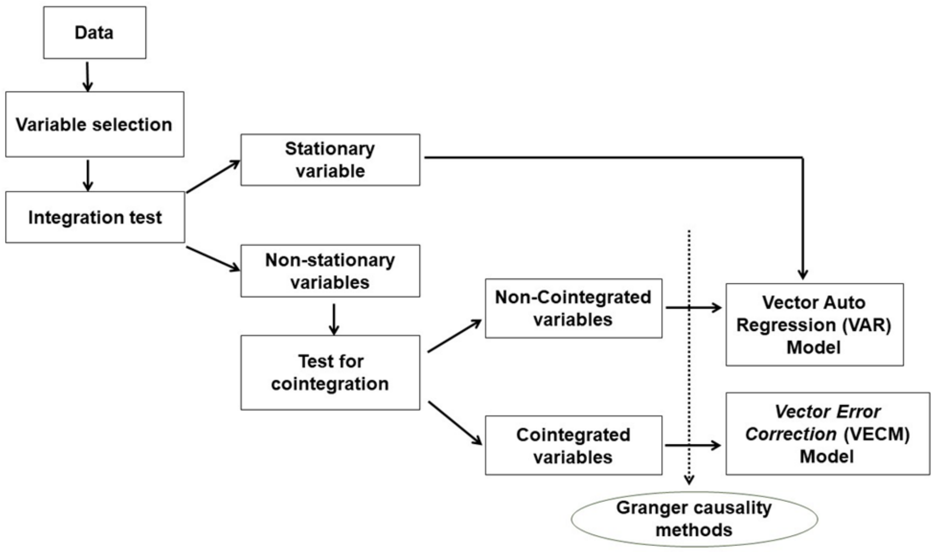

Figure 1. Test Stages in Granger Causality.

The first step is to use a preliminary statistical test to verify stationarities for all variables. This is conducted through the usual unit root method, which is known as the Augmented Dickey-Fuller test (ADF). Also, this step is important for two reasons, (1) The causality test is highly sensitive to serial stationarity, and (2) Most of the time-series data for macroeconomic indicators are non-stationary. The ADF test is very popular for testing sequence integration of variables. Empirically, equation 1 is represented as follows:

$$\Delta y_t = x_t b + \delta y_{t-1} + \sum_{i=1}^{m} a_1 \Delta y_{t-1} + \varepsilon_t \quad (1)$$

Where y_t = time series to be tested, x_t = the selected exogenous regressor that contained constants and trends, a and b = the parameters that should be estimated, ε_t = the white noise error terms, m = the maximum lag length determined using Schwarz information and Akaike Information Criteria (SIC & AIC), and Δ = delta. According to the second step, when both series were integrated from the same order, the lag length was determined through the AIC and SIC, with the presence of cointegration also checked. Furthermore, the null hypothesis (H0: $\delta = 0$) was tested against the alternative (Ha: $\delta < 0$). When the null hypothesis is true, the existence of a unit root is confirmed, with the series observed as non-stationary. However, when the null hypothesis is rejected, stationary series are indicated.

Based on this study, the cointegration test was carried out through the Johansen method, by focusing on the statistical value of the Trace and Maximum-Eigen analysis value. The Vector Error Correction Model (VECM) is used when variables are co-integrated. However, when not co-integrated, the Vector Auto Regression (VAR) model is used. Therefore, the general model for the regression is shown as follows (Maparu & Mazumder, 2017):

$$y_t = \sum_{i=1}^{p} \beta_i y_{t-i} + \gamma x_t + u_t \quad (2)$$

Where, y_t = the vector of the non-stationary variable k I (1), x_t = the vector of the deterministic variable, β_i and γ = the parameters to be calculated, u_t = the innovation vector, and p = the VAR sequence.

According to the Granger Causality Test for equation (2), a variable (x) was stated to be a Granger causal to the other (y). This was observed when the lagging value of x increased the predictability of y, provided that other data were present. Moreover, the bivariate causality was divided into 3 categories, as follows: (1). Unidirectional: This causality was direct from x to y, when the coefficient on lagged x_t was significantly different from zero as a group. It was also directed from x to y, when y_t is the dependent variable and the coefficient on lagged y_t does not differ significantly from zero. The causality was also directed from x to y when x_t is the dependent variable. (2). Bidirectional: This indicated a relationship between x and y when the coefficient on the lagged x_t significantly differed from zero as a group. Moreover, it indicated a relationship, when y_t is the dependent variable. The coefficient on lagged y_t was significantly different from zero, when x_t is the dependent variable. (3). Independence: The causality occurred when the coefficients on x_t and y_t lagged were significantly different from zero in both equations.

If the variables are cointegrated, Vector Error Correction Model (VECM) can be used instead of VAR. Equation 3 shows the general model for VECM.

$$\Delta y_t = \sum_{i=1}^{q} \beta_i y_{t-i} + \emptyset x_t + \gamma ECT_t + u_t \quad (3)$$

Where, Δ is the first difference operator, β_i and $\emptyset$ = the parameters to be calculated, u_t = the white noise error terms, and q = the maximum lag length.

Vector Error Correction Model (VECM) can be made for testing Granger causality between the variables of CO2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment. The empirical equation of VECM is presented as follow:

$$\begin{bmatrix} \Delta \mathrm{LCO2}_t \\ \Delta \mathrm{UD}_t \\ \Delta \mathrm{LEG}_t \\ \Delta \mathrm{LX}_t \\ \Delta \mathrm{LM}_t \\ \Delta \mathrm{FDI}_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{j=1}^{L} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} & \beta_{35j} & \beta_{36j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} & \beta_{45j} & \beta_{46j} \\ \beta_{51j} & \beta_{52j} & \beta_{53j} & \beta_{54j} & \beta_{55j} & \beta_{56j} \\ \beta_{61j} & \beta_{62j} & \beta_{63j} & \beta_{64j} & \beta_{65j} & \beta_{66j} \end{bmatrix} \begin{bmatrix} \Delta \mathrm{LCO2}_{t-j} \\ \Delta \mathrm{UD}_{t-j} \\ \Delta \mathrm{LEG}_{t-j} \\ \Delta \mathrm{LX}_{t-j} \\ \Delta \mathrm{LM}_{t-j} \\ \Delta \mathrm{FDI}_{t-j} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} \mathrm{ECT}_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \quad (4)$$

Where α and γ are the coefficients to be estimated. ECT_{t-1} is the lagged residual term derived from the long-run relationship. If γ negative and significantly different from zero, it is a long-term interplay. L is the maximum lag length, Δ is the first difference operator dan ε is the error terms.

Recall equation 4. We can break it down into the following equations:

$$\Delta \mathrm{LCO2}_t = \alpha_1 + \sum_{j=1}^{L} \beta_{11j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{12j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{13j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{14j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{15j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{16j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_1 \mathrm{ECT}_{t-1} + \varepsilon_{1t} \quad (5)$$

$$\Delta \mathrm{UD}_t = \alpha_2 + \textstyle\sum_{j=1}^{L} \beta_{21j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{22j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{23j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{24j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{25j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{26j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_2 \mathrm{ECT}_{t-1} + \varepsilon_{2t} \quad (6)$$

$$\Delta \mathrm{LEG}_t = \alpha_3 + \textstyle\sum_{j=1}^{L} \beta_{31j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{32j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{33j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{34j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{35j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{36j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_3 \mathrm{ECT}_{t-1} + \varepsilon_{3t} \quad (7)$$

$$\Delta \mathrm{LX}_t = \alpha_4 + \textstyle\sum_{j=1}^{L} \beta_{41j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{42j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{43j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{44j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{45j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{46j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_4 \mathrm{ECT}_{t-1} + \varepsilon_{4t} \quad (8)$$

$$\Delta \mathrm{LM}_t = \alpha_5 + \sum_{j=1}^{L} \beta_{51j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{52j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{53j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{54j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{55j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{56j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_5 \mathrm{ECT}_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \mathrm{FDI}_t = \alpha_6 + \sum_{j=1}^{L} \beta_{61j}\, \Delta \mathrm{FDI}_{t-j} + \sum_{j=1}^{L} \beta_{62j}\, \Delta \mathrm{LCO2}_{t-j} + \sum_{j=1}^{L} \beta_{63j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{64j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{65j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{66j}\, \Delta \mathrm{LM}_{t-j} + \gamma_6 \mathrm{ECT}_{t-1} + \varepsilon_{6t} \quad (10)$$

The long-term equilibrium is shown by the negative ECT coefficient. It indicates a correction of the variable movement towards its long-term equilibrium, hence, the coefficient should be negative. This indicates the closer to zero of the coefficient values, the quicker the adjustment towards long-run equilibrium.

4. Results and Discussion

4.1. Empirical Results

Before examining cointegration between variables, we present an overview related to CO2 emissions in Indonesia during the period 1971-2019. This is necessary to find out its role towards net zero emission through Vector Error Correction Model.

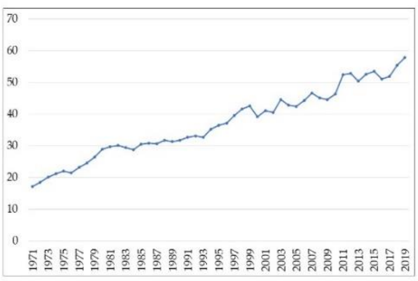

Figure 2. Time trend of CO2 Emissions

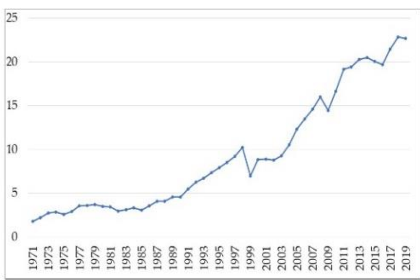

Figure 5. Time trend of Export

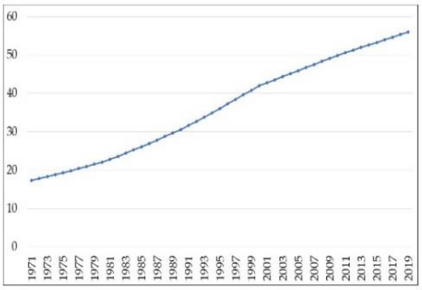

Figure 3. Time trend of Urbanization

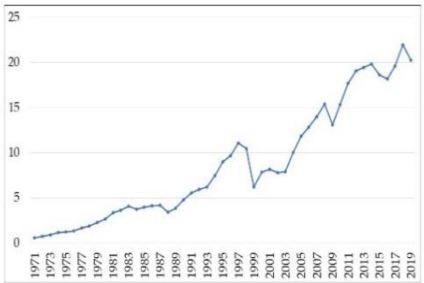

Figure 6. Time trend of Import

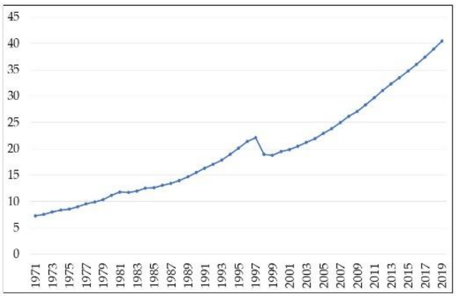

Figure 4. Time trend of Economic growth

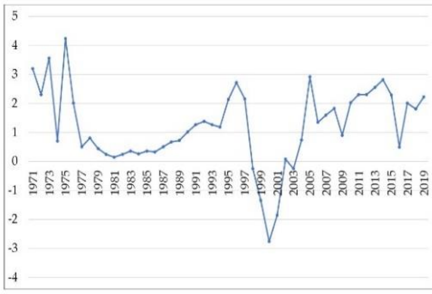

Figure 7. Time trend of Foreign Direct Investment

Figure 2 shows trends in CO2 emissions that have occurred since 1971, tend to increase. It implies that significant growth in emissions has occurred since 1971, accompanied by increasing urbanization and economic growth (Figure 3 and Figure 4). Prior to the economic crisis in 1998, an international agreement did not influence the reduction of CO2 emission in Indonesia. Carbon emission constantly raised up after the first United Nation Environmental Conference which was conducted in Stockholm in 1971. Since 1998, a significant increase in economic activities, such as exports and imports (Figure 5 and Figure 6), have been led to a relatively higher emission. The Kyoto Protocol, which was signed in 1997, made the trend of carbon emissions fluctuate, as well as a Paris Agreement in 2015. It implies the influence of international agreement diplomacy on economic activities related to the reduction of CO2 emissions. Figure 6 shows the volatile of FDI net inflows. Since the heaviest economic crisis in 1998, foreign direct investment has tended to increase. Global shocks had brought it down in 2008 and 2016 but could rise again at the end of 2019. This confirm that the interest of investors to Indonesia is still high.

The dynamic causal relationship between CO2 emissions, urbanization, economic growth, export, and import activities, as well as foreign direct investment, was carried out through several steps. Firstly, each variable containing the unit root was checked. Secondly, the test to determine whether there was a long-term cointegration relationship between the variables was conducted. Thirdly, the estimation of the VECM to deduce the Granger causal relationship between the variables was carried out. A summary of the results is shown in Table 4 based on the first stage, which is the unit root identification of each variable.

Table 4. Root Test of ADF-PP.

Variable	ADF		PP	
	t-statistic	**Prob.**	**t-statistic**	**Prob.**
Level				
LCO2	-1.802599	0.3748	-2.454673	0.1329
UD	-1.697425	0.4258	0.198221	0.9697
LEG	-0.618192	0.8566	-0.606277	0.8593
LX	-0.630870	0.8536	-0.601572	0.8603
LM	-2.536889	0.1135	-2.592632	0.1016
FDI	-3.296863	0.0206	-3.348542	0.0181
First difference				
LCO2	-5.806780	0.0000*	-7.190028	0.0000*
UD	-1.579417	0.4848	-1.648529	0.4502
LEG	-5.103162	0.0001*	-5.072025	0.0001*
LX	-8.107578	0.0000*	-8.160933	0.0000*
LM	-6.087550	0.0000*	-6.087550	0.0000*
FDI	-9.123195	0.0000*	-9.067042	0.0000*
Second difference				
UD	-6.02711	0.0000*	-5.980405	0.0000*

Remarks: * significant at the 1% level

The first stage was the ADF unit root test, which showed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment were not stationary in the level integration analysis (table 4). Furthermore, the first difference was conducted on all stationary variables I (1), except for the UD. This indicated that there was a difference in the level of stationarity within the UD variable, as the Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), Fisher-ADF, and Fisher-PP tests were carried out, respectively. The summary of the result is shown in Table 5. Based on the use of the Levin-Lin-Chu, Pesaran-Shin, and ADF-PP methods, the first difference root test showed that all results were stationary at I (1), due to the probability which was less than 5%. This also confirmed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment, were tested for cointegration.

Table 5. Group Unit Root Test.

Method	Level		First Different	
	Statistic	**Prob.**	**Statistic**	**Prob.**
Levin, Lin & Chu t*	-0.23198	0.4083	-7.51263	0.0000*
Im, Pesaran and Shin W-stat	-0.50251	0.3077	-12.0491	0.0000*
ADF - Fisher Chi-square	15.9249	0.1947	133.866	0.0000*
PP - Fisher Chi-square	15.4927	0.2156	135.685	0.0000*

Remarks: * significant at the 1% level
Number of observations 276.

The optimal lag length was determined based on the Akaike Information Criterion (AIC). According to the determination of the most optimal lag, the highest LR and low AIC, HQIC, and SBIC values were observed. The results showed the optimal lag length used was 2, through the consideration of the lowest AIC value. Subsequently, a stability test was conducted to determine the usable model (VAR or VECM). The result also showed the variables to be used met the stability criteria, as the modulus values were less than 1, hence, the VAR or VECM was used.

After passing the stability analysis, the cointegration test was conducted. Furthermore, the Johansen Cointegration test was found to be based on the linear determinism assumption (intercept and trend). A long-term balance was observed when the Trace or Max-Eigen values were more than the critical value of 5%. Therefore, the results of the

Johansen Cointegration Test based on Trace and Max-Eigen Statistics are summarized in Table 6.

Table 6. Johansen Cointegration Test.

Hypothesis	Eigenvalue	Trace-test		Max-Eigen test	
		Statistic	ρ value	Statistic	ρ value
None	0.731063	136.8953	0.0000*	60.41077	0.0001*
At most 1	0.504075	76.48456	0.0133**	32.26119	0.0770
At most 2	0.361128	44.22337	0.1054	20.61038	0.3004
At most 3	0.242559	23.61299	0.2173	12.77925	0.4727
At most 4	0.159968	10.83374	0.2219	8.018521	0.3768
At most 5	0.059365	2.815217	0.0934	2.815217	0.0934

Remark: * Significant at the 1% level; ** Significant at the 5% level.

The null hypothesis of Johansen's test stated that cointegration occurred when at least one analysis was cointegrated. The null hypothesis was accepted based on the result, which showed Trace and Max-Eigen test values of 2 and 1 cointegrations at the 0.05 level, respectively. This indicated that there was cointegration between variables, as CO2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment, had a long-term relationship within the period of 1971 to 2019 in Indonesia. These variables were also eligible for the VEC framework.

Based on the use of VECM, the causality source was identified from the significance test that was conducted for the coefficient of the independent variable. According to the short-term causality, the Granger Causality/Block Exogeneity Wald Tests was used to determine the nullity of the parameters associated with the independent variable in each VECM equation, through the $\chi 2$-Wald statistic. However, causality in the long term was tested by the significance of the adjustment speed. The t-statistic of the ECT coefficient that showed a long-term causal effect was also used.

Table 7. Granger Causality/Block Exogeneity Wald Tests.

Dependent variable	Short Run						Long Run	
	ΔL(CO2)	ΔUD	ΔL(EG)	ΔL(X)	ΔL(M)	ΔFDI	Coefficient	t-test
ΔL(CO2)	-	18.72401 (0.0001) *	6.126103 (0.0467) **	1.802927 (0.406)	10.50891 (0.0052) *	31.76471 (0.000) *	-0.863939	-7.31613*
ΔUD	0.885313 (0.6423)	-	0.894056 (0.6395)	1.505821 (0.471)	9.9198 (0.007) *	0.759596 (0.684)	0.62141	1.15879
ΔL(EG)	0.020633 (0.9897)	3.397833 (0.1829)	-	0.255068 (0.8803)	0.241267 (0.8864)	1.068797 (0.586)	-0.126233	-0.80081
ΔL(X)	2.835755 (0.2422)	2.549941 (0.2794)	16.40749 (0.0003) *	-	0.363593 (0.8338)	0.042006 (0.9792)	0.518394	1.31906
ΔL(M)	2.0033835 (0.3673)	1.69154 (0.4292)	30.15772 (0.0000) *	2.537506 (0.2812)	-	0.027722 (0.9862)	-0.017462	-0.03758
ΔFDI	2.94009 (0.2299)	4.537871 (0.1034)	2.024757 (0.3634)	1.783195 (0.4100)	3.849635 (0.1459)	-	11.73753	1.06675

Remark: * Significant at the 1% level; ** Significant at the 5% level; *** Significant at the 10% level

Table 7 shows 3 out of 6 vectors had a negative value of ECT-1, but only equation 3 was statistically significant at a 1% significance degree. This means only CO2 emissions had an equilibrium in the long-term. Also, unidirectional causality occurs from urbanization, economic growth, exports, and foreign direct investment to CO2 emissions in the short-term. Likewise, imports into urbanization and economic growth had a one-way relationship to exports and imports (Table 5 and Figure 2).

4.2. Impulse Response

Impulse response CO2 emissions to urbanization showed that the urban density was included in the counter-urbanization phase in the short-term. This phase is characterized by a decrease in the environmental, physical, and socio-economic carrying capacity of the population in the larger metropolitan area (Sarungu, 2001). The high level of urbanization can result to a rapid population growth which leads to agglomeration and will be followed by efforts of people to fulfill the needs. Due to the speed and scale of escalation in these cities, they can induce great pressure on the environment and pose environmental degradation or threat to sustainable development (Cohen, 2006). This result is in line with Agung PS et al. (2017) and Liang et al. (2019). In the long-term, CO2 emissions will decrease along with the awareness of city dwellers on the importance of health and quality of life. This is consistent with the negative response of CO2 emissions to urban density (figure 3b). Therefore, urbanization can be directed to reduce CO2 emissions by using the potential spillover of technology and high levels of education. This is consistent with Liu & Liu (2019), Hassan et al. (2020), and S. Wang et al. (2020).

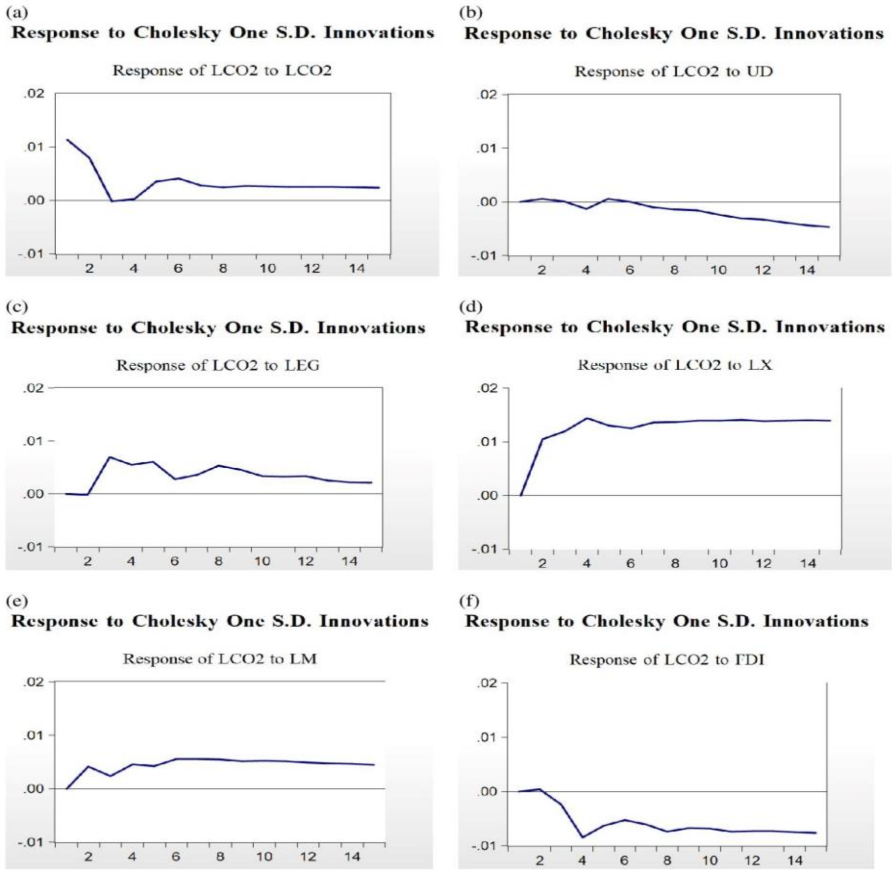

Figure 3. Impulse response functions.

Assumed FDI changes, the response of CO2 emissions was positive in the short run, but was negative in the third year, reaching its lowest point in the fourth year, and subsequently tends to move steadily (figure 3f). The positive response of CO2 emissions during the shock in FDI was consistent with the VECM estimation in this study. It also showed an increase in FDI in the long-run, leading to environmentally oriented investment. This is in line with Adams et al. (2020), Salehnia et al. (2020) and (Z. Chen et al., 2021). This is a great target that developing countries should build upon in order to realize Halo Pollution Hypothesis, along with the increasing FDI values every year. The responses of CO2 emissions to export and import economic activities were positive. Figure 3 shows a shock to exports will increase CO_2 emissions sharply until the fourth year, and subsequently the changes tend to be stable in the long-term. The same pattern was shown by imports. Although the response to CO_2 emissions was smaller than the shock to exports, it was also positive to changes in imports. This is a formidable challenge towards net-zero carbon. Actually, the policy of goods or commodities received from the rest of the world for Indonesian consumption has led to the procurement of cordial environmental commodities which minimizes the occurrence of CO_2 emissions. The Government of Indonesia issued Statute Law Number 32 (UU No 32) in 2009 concerning Environmental Protection and Management (UU PPLH) as well as Statute Law Number 18 (UU No 18) in 2008 concerning Waste Management (UU Waste Management). It was subsequently strengthened by the stipulation of Statute Law Number 7 (UU No 7) in 2014 concerning Trade, specifically Article 50 paragraph (1) and (2) which states that all goods can be exported or imported, except those prohibited, restricted, or otherwise stipulated by law. The newest implementation is regulated in Government Regulation No. 22 (PP No 22) in 2021 concerning the implementation of environmental protection and management. The climate change emergency at COP26 is time-bound, making net zero carbon policy mandatory for companies. Based on the results of variance decomposition (Table 6), the largest contribution to emissions comes from export activities. Therefore, failure to immediately adapt to a net zero carbon policy can lead to loss of global market share.

4.3. Variance Decomposition

Initially, the largest contribution to CO_2 emissions in the short-term is the variance in the variable itself, but its contribution decreased afterward. The largest contribution was taken over by the export. Initially, it contributed only 34%, but increased continuously to become the largest at the end of the period (Table 8). The economy growth, FDI, urbanization, and imports also showed an increasing trend of contributions.

Table 8. Variance Decomposition of LCO2.

Period	S.E.	Illustrated by variable (%)					
		LCO2	UD	LEG	LX	LM	FDI
1	0.01126	100	0	0	0	0	0
2	0.01778	60.0086	0.08991	0.00916	34.4567	5.39887	0.03685
3	0.02273	36.7204	0.05502	9.20014	48.4918	4.34863	1.18405
4	0.02912	22.3715	0.24277	9.14684	53.8769	5.08307	9.27894
5	0.03352	17.9672	0.20705	10.1653	55.6899	5.41679	10.5537
6	0.03693	15.9996	0.17066	8.9383	57.3913	6.7383	10.7619
7	0.04047	13.7793	0.21075	8.2149	59.0947	7.45419	11.2462
8	0.04409	11.9095	0.28457	8.34995	59.3394	7.81342	12.3031
9	0.04731	10.6518	0.36451	8.16321	60.1271	7.9719	12.7215
10	0.05029	9.69206	0.56157	7.65746	60.8523	8.11226	13.1244
11	0.05324	8.86569	0.83062	7.21289	61.2709	8.17552	13.6444
12	0.05596	8.22208	1.10796	6.87468	61.5566	8.15348	14.0852
13	0.05855	7.68971	1.4459	6.46236	61.8715	8.09846	14.4321
14	0.06108	7.21843	1.83961	6.06841	62.0817	8.00712	14.7847
15	0.06353	6.80859	2.24968	5.71815	62.1948	7.8946	15.1342

The biggest contribution from export activities to CO_2 emissions should be the main notice related to Indonesia's commitment to achieving net-zero carbon by 2070. It should also be noted that international agreements to reduce CO_2 emissions were more or less efficient, but on the other hand, it has reduced the competitiveness and exports of several countries (C. H. Wang et al., 2019). Some countries in Asia, Europe, and America have implemented climate change mitigation programs to reduce the emissions, which influences the trading regulation. Requirements are set to the product, hence, it can be accepted globally by fulfilling sustainability requirements. For example, low-emission industrial products companies do not carry out deportation or execute forest conservation policies.

Foreign direct investment contributes to economic growth (Omri et al., 2014). It recognizes that investment, advanced technology, and knowledge can be transferred from industrialized countries to developing countries as an important asset to increase economic growth (Raz et al., 2012). Therefore, FDI can accelerate the speed of General Purpose Technologies (GPT) as the engine of growth. However, in some countries, the existence of this investment turns out to provide negative externalities to the environment, thereby proving the Pollution Haven Hypothesis (Aliyu, 2005; Aljawareen, 2017). The result showed foreign direct investment contributed significantly to CO2 emissions. Economic agents should anticipate carefully in order to remain competitive in the global economy due to climate change. For example, European Union makes policies regarding Sanitary and Phytosanitary to protect human and animal health, as well as environmental requirements (sustainable forest certificates and ecolabels, origin of products) for wood commodities. Other requirements, such as health and safety (free of fluorocarbon and formaldehyde emissions) and expensive costs are also not handly to manage. These should be borne by Indonesian entrepreneurs. Similarly, the Japanese government has a standard for wood products (Japan Agricultural Standard, JAS) and other export destination countries. Therefore, the right strategy is needed to synergize between economic growth air quality. Although economic activities should be carried out, it needs to be balanced in order to achieve net zero carbon.

5. Conclusions

This study aims to analyse the pattern of urbanization, economic growth, export, import, foreign direct investment, and CO2 emissions. It also proved whether the halo or haven pollution hypotheses exist in Indonesia from 1971 to 2019. According to the result, CO2 emissions had an equilibrium in the long-term. Also, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO2 emissions in the short-term. Likewise, imports into urbanization and economic growth indicated a one-way relationship to exports and imports. This consequently strengthened the IPAL Model by Dietz & Rosa (1997) which stated that population, income, and technology are considered as the main drivers of environmental impact.

The pollution haven hypothesis exists in Indonesia and FDI had a one-way interplay with CO2 emissions. The government should regulate air pollution by conditioning urbanization to be environmentally friendly through building several green open spaces and public transportation that uses accommodative fuel or renewable energy. Gradually, capital should be directed to investments that promote the economy to thrive. Foreign investment is used as a pillar to support the realization of a green urban development model. This is achieved by limiting negative environmental externalities through procurement and physical investment, particularly in power generation, transportation, and manufacturing industries.

Countries which are committed to climate change prevention in the Paris Agreement, should compile the long-term development plans that are integrated with strategies to reduce the amount of greenhouse gas emissions. In other words, the target for reducing emissions in its implementation needs be coherent with several existing policies, specifically Indonesia's ambition to escape from the middle-income traps. The toughest challenge for the country is the use of coal energy sources. The transfer of coal plants to renewable energy in 2040 requires the support of international cooperation, technology, economic feasibility, and international funding to assist the energy transition. Therefore, the formation of a healthy and prosperous state ecosystem can be achieved when there is collaboration from all economic agents.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used

"Conceptualization, D.M.N., I.M., L.H. and S.S.; methodology, D.M.N, and L.H.; software, D.M.N; validation, I.M., L.M., and S.S; formal analysis, D.M.N., and L.H.,; investigation, D.M.N.; resources, D.M.N. and S.S.; data curation, L.H., and S.S.; writing—original draft preparation, D.M.N; writing—review and editing, D.M.N., I.M., L.H. and S.S.; visualization, D.M.N.; supervision, I.M; L.H. and S.S.; project administration, D.M.N.

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CO^2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon

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Abstract: This study aims to analyze the nexus between CO^2 emissions, urbanization, and economic activity, as well as identify whether the pollution haven hypothesis is proven in Indonesia. It utilized time series data of Indonesia during the 1971–2019 period. Furthermore, the vector error correction model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship with CO^2 emissions was observed from the model. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short term. It was concluded that the achievement of the Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed, where all parties need to have the same vision towards net zero carbon.

Keywords: CO2 emissions; economic activities; urbanization; net zero carbon

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1. Introduction

The 2021 UN climate change conference (COP26) was held in Glasgow, Scotland, on 31 October–12 November 2021. This event is an extension of the Paris Agreement and serves as a reminder that a big agenda needs to be immediately carried out to address climate change due to human activities. Several countries are challenged with the trade-off between economic growth and environmental degradation. The environmental Kuznets curve (EKC) hypothesis explains an inverted U-shaped relationship between economic growth and environmental degradation. This means environmental pressure increases in the early stages of economic growth due to the increased release of pollutants as well as extensive and intensive exploitation of natural resources associated with greater use of production (Grossman and Krueger 1991; Özokcu and Özdemir 2017; Shahbaz et al. 2019; Rahman et al. 2020).

Also, it is found that the efforts to reach a turning point are challenging in terms of improving environmental quality. CO^2 emissions are increased when economic development activities are high. This indicates that the quicker the regional economic growth, the worse the air pollution (Hossain 2011; Ben Abdallah et al. 2013; Hasanov et al. 2018).

Before the pandemic, Indonesia was ranked as one of the world's emerging markets at the end of 2019. In fact, the economic growth has been reasonably consistent at about 5.1% in 2019 due to the strong trust of foreign investors. However, in 2015, Indonesia became the fourth-largest emitter of greenhouse gases, which is a major source of concern.

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According to the World Bank Indicators released in 2020, there was an increase in CO^2 emissions of 4.4%/year on average between 2001 and 2018. The highest increase and lowest decrease in the emissions occurred in 2011 and 2013 at 14.8% and 7.5%, respectively. Furthermore, the economic performance increased by 0.1–0.28 points, but the air quality decreased by more than 10%, a condition that will be a threat to Indonesia. According to the World Bank, about 220 million Indonesians will live in cities and towns by 2045. Consequently, the high population density will lead to accelerated economic activity in the region. This is in line with Liang et al. (2019), who stated that rapid urbanization will promote social and economic development but raise some environmental pollution problems (Camagni et al. 1998). This implies that environmental quality will deteriorate as more resources are used to promote economic activity.

COP26 provides momentum for the nation to prepare risk mitigation in international trade with the application of levies on carbon emissions. Empirical studies related to the influence of international trade in Indonesia showed different results. Bhattacharya et al. (2019) found that there was no significant effect between trade openness and CO^2 emissions. Meanwhile, Nathaniel (2020) stated that Indonesian trade can reduce natural CO^2 emissions in the short-term but exacerbate environmental degradation in the long-term. The open economic system has contributed to CO^2 emissions (F. Chen et al. 2021); therefore, this study focused more specifically on the relationship between exports and imports of CO^2emissions due to the carbon emission tax policy on international trade. In addition, it harbors suspicion about the two responses that are different from CO^2 emissions; hence, separate identification is needed to determine the final policy. Studies of exports and imports have provided different results. Exports promote an increase in emissions (Salehnia et al. 2020) and also improve environmental quality (Hasanov et al. 2018; Pié et al. 2018). The result of import activities showed that imports cause environmental degradation (Hasanov et al. 2018; Pié et al. 2018; Salehnia et al. 2020), while Aljawareen and Saddam (2017) stated that it is a stimulus for improving air quality.

In advance, the existence of the pollution haven hypothesis needs to be tested. Salahuddin et al. (2019) used the link between trade openness induced by globalization to prove the pollution haven hypothesis. Meanwhile, this study examines whether foreign direct investment results in increased CO^2 emissions. The reinforcing reason is that Indonesia has great potential for foreign investment. According to the United Nations Conference on Trade and Development (UNCTAD), Indonesia is among the top 20 developing countries that were the destination for FDI globally in 2017 and 2018. Hence, the relationship between investment and the environment in these countries can be examined to prove the pollution haven hypothesis. Based on previous studies, there is a two-way relationship between FDI and CO^2 emissions (Tang and Tan 2015; Omri et al. 2014). The connection between CO^2 emissions and FDI will be beneficial to the environment when the pollution haven hypothesis is not discovered (Z. Chen et al. 2021). Meanwhile, Omri et al. (2014) stated that FDI had a unidirectional relationship and a positive effect on CO^2 emissions in Qatar. Kizilkaya (2017) discovered that foreign direct investment was ineffective on CO^2 emissions in Turkey. Therefore, this study aims to analyze the interplay of urbanization, economic growth, exports, imports, foreign direct investment, and CO^2 emissions. It also proves whether the pollution halo or haven hypotheses existed in Indonesia from 1971 to 2019. It is of prominent importance to developing countries or those highly dependent on international trade, related to the global commitment to reducing carbon emissions and the transition process toward a low-carbon country.

The theoretical basis and previous empirical studies are presented after the background of the study to comprehend the relationship between urbanization, economic growth, export, import, foreign direct investment, and CO^2 emissions. Afterward, the methods section provides an overview of the variables used, and the stages carried out. The next section presents the results, which are subsequently deepened by the discussion, as well as the conclusions and policy implications.

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2. Literature Review

The relationship between urbanization and environmental quality is founded on the concept of an urban area in which demand-driven activities center on cost reduction. This is due to its closeness to other regions with similar proximity, endowment resources, and high population density. In addition, because of this association, people are able to rationally relocate to urban areas. Urbanization is formed through socio-economic development. According to Pernia et al. (1983), population growth is often higher in rural areas than urban areas. This indicates that there is a direct demographic effect, which involves reducing the proportion of urban areas. It was also stated that population growth hampers economic development. This indicates that urbanization is either influenced directly or indirectly by socio-economic development, through population growth. Meanwhile, Firebaugh (1979) stated that it is influenced directly and indirectly by the deterioration of rural conditions and economic development, as well as previous urbanization, respectively. Hence, urbanization theory should consider the conditions in rural and urban areas because it is applied to both developed and developing countries.

The migration of people to urban areas is carried out through different phases of the urbanization process as follows (Sarungu 2001). Firstly, there is agrarian urbanization, which entails innovation in agricultural technology application and leads to an increase in assertive productivity. Secondly, there is urbanization in industrialized metropolitan areas. It is characterized by an increasing concentration of population and economic activity in the vicinity of major cities, as well as substantial infrastructure investment to facilitate efficient export and import operations (Turok and McGranahan 2013). Thirdly, in a growing metropolitan area, there is a postindustrial non-metropolitan counter urbanization, which is characterized by a reduction in the population's physical and socioeconomic capacity.

The findings of empirical studies showed different results. Urbanization and pollution have bidirectional causality (Santillán-Salgado et al. 2020; Nosheen et al. 2020; Salahuddin et al. 2019; Amin et al. 2020; Abbasi et al. 2020;), while there is a one-way causality between urbanization and CO^2 (Ponce and Alvarado 2019; Bashir et al. 2021). Specifically, several empirical studies were conducted to determine the process that occurs in post-industrial non-metropolitan counter-urbanization. Urban regions, road area per capita, and GDP were found to have negative effects on CO^2 emissions (Qiu et al. 2019). Therefore, it needs to be controlled with careful planning and mitigation of CO^2 emissions (Yang et al. 2015; Hassan et al. 2020) because emissions and urbanization have a relationship (Santillán-Salgado et al. 2020).

Previous studies showed an inverted U-shaped relationship between economic growth and environmental degradation which is in line with the environmental Kuznets curve (EKC) hypothesis (Borhan et al. 2012; Lin and Zhu 2018; Hanif 2018; Tang and Tan 2015; dan C. H. Wang et al. 2019). An initial study by Grossman and Krueger (1991) and Tanger et al. (2011) reported the inverse relationship between CO^2 emissions and economic growth. The interesting outcome was presented by Hossain (2011) and Hossain (2012), which stated that several literatures had failed to establish an inverse U relationship with the real-life data. Particularly in developed and developing countries, the studies that examined the causal relationship between energy consumption and growth produced three different results. Other studies reportedly discovered two-way causation, as well as unidirectional causes and causality direction from output growth to energy consumption.

Economists also conducted studies on the relationship between FDI and economic growth. Externalities were transferred from industrialized to developing countries, based on the assumption that FDI is an important asset to boost greater development. According to developing countries, the investment served as a means of transferring factors, due to the accelerating pace of general purpose technologies (GPT), while introducing advanced technology and science. This means the countries exploited these factors as assets to increase economic growth. Furthermore, FDI defines economic openness from a financial standpoint, which has been proven to promote economic growth, although this has not been shown in the United States (Omri et al. 2015). The consequence of this openness is the emergence of negative externalities. The pollution haven hypothesis was developed from the studies of Copeland and Taylor (1994) and Chen et al. (2021). Based on this hypothesis, three dimensions (Aliyu 2005) were observed. Firstly, heavily polluting enterprises relocated from industrialized to developing countries, where strict environmental regulations were not enforced. Global free trade, on the other hand, has increased industrial and polluting activities by relocating to nations with weak environmental policies. Secondly, the transfer of hazardous waste from developed to developing countries (industrial production and nuclear energy). This issue was also the subject of the Basle Convention on hazardous waste. Thirdly, multinational companies involved in the production of petroleum and its products, as well as lumber and other forest resources, including the extraction of non-renewable natural resources in developing countries without control. These factors are related to conscious environmental policy decisions and how they impact the environment, production, and future trade. However, the pollution haven hypothesis has two empirical consequences, namely (1) FDI outflows in developed countries are positively correlated with environmental policy tightening, and (2) Pollution in developing countries is positively correlated with the inflows of FDI. The existence of foreign investment brings technological efficiency compared to those within the country (Balogh and Jámbor 2017; Adams et al. 2020; dan Salehnia et al. 2020). In addition, Aljawareen and Saddam (2017) showed that FDI had a positive interplay with CO^2 emissions in Qatar. The selected studies about the pattern of CO^2 emissions, urbanization, and economic activities are summarized in Table 1.

Table 1. Literature review of pattern of CO2 emissions, urbanization, and economic activities.

Authors	Country/Region (Periods)	Technique Analysis	Findings
	Economy Growth and CO^2 emissions		
Rahman et al. (2020)	5 South Asian Countries (1990–2017)	Granger causality, VECM FMOLS, DOLS, generalized method of moments (GMM)	ECO^2 + EG EG ↔ ECO^2
C. H. Wang et al. (2019)	5 Countries: Germany, Italy, India, Taiwan and Japan (1950–2010)	*Rolling regression*	EG ∩ ECO^2
Vo et al. (2019)	ASEAN 5 (1971–2014)	Granger causality, FMOLS, DOLS	EG → ECO^2
Abbasi et al. (2020)	8 Asia Countries (1982–2017)	Granger causality.	EG ≠ $ECO^2$2
Chikaraishi et al. (2015)	140 Countries (1980–2008)	Laten STIRPAT model	EG − ECO^2
(Batool et al. (2021)	ASEAN 5 (1980–2018)	Granger causality, VECM	EG + ECO^2 EG ≠ ECO^2 (Ind, Mal) LR: EG ↔ ECO^2 (Ind, Tha) SR: EG → ECO^2 (Phi, Sgp)
Joshua et al. (2020)	South Africa	ARDL	EG + ECO^2 EG → ECO^2
Phong et al. (2018)	Vietnam (1985–2015)	ARDL	EG + ECO^2
Bashir et al. (2019)	Indonesia (1985–2017)	VECM	EG ≠ ECO^2,
	Urbanization and CO^2 emissions		
Salahuddin et al. (2019)	South Africa (1980–2017)	Unit root tests (Zivot and Andrews single, dan Bai dan Perron), cointegration, ARDL	U ↔ ECO^2
Al-Mulali et al. (2013)	MENA Countries (1980–2009)	Pedroni's cointegration, panel Granger causality	U ↔ ECO^2 U + ECO^2

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Hanif (2018)	34 Countries in Africa (1995–2015)	System generalized method of moment (GMM)	U + ECO_2
Adedoyin and Bekun (2020)	7 Countries (1995–2014)	Panel VAR approach, FMOLS, pooled mean group–ARDL	U ↔ ECO_2
H. S. Ali et al. (2017)	Singapore (1970–2015)	ARDL	U – ECO_2
R. Ali et al. (2019)	Pakistan (1972–2014)	ARDL, VECM	U + ECO_2 U → ECO_2
Bekhet and Othman (2017)	Malaysia (1971–2015)	VECM, Granger causality	LR: U ↔ ECO_2 , Inv. Domestic ↔ E CO_2 SR: U → E CO_2, U → EG, Inv. Domestic → EG
Martínez-Zarzoso and Maruotti (2011)	Developing countries (1975–2003)	LSDVC, GMM methods	U ∩ ECO_2
Akorede and Afroz (2020)	Nigeria (1970–2017)	Causality tests, ARDL	U – ECO_2
Lin and Zhu (2018)	282 Cities in China (2012)	Bayesian model average	U – ECO_2
Ergas et al. (2016)	USA (2002–2007)	*A hybrid panel model*	U – ECO_2
Borhan et al. (2012)	8 East Asia	Simultaneous equation	ECO_2-U
Dong et al. (2019)	14 Countries maju	Two fixed-effect panel threshold models	SR: U ≠ECO_2 Middle Run : U – ECO_2
	Economic Activities and CO_2 emissions		
Kizilkaya (2017)	Turkey (1970–2014)	ARDL	FDI ≠ ECO_2
Tang and Tan (2015)	Vietnam (1976–2009)	Cointegration, Granger causality	FDI ↔ ECO_2
Hasanov et al. (2018)	Azerbaijan, Bahrain, Kuwait, Oman, Qatar, Russia, Saudi Arabia, United Arab Emirates (UAE) and Venezuela (1995–2013)	PDOLS, PFMOLS, PMG methods, panel ECM	X – ECO_2 M + ECO_2
Aljawareen and Saddam (2017)	6 GCC Countries (1998–2008)	Panel data	FDI + ECO_2 (Qatar) M – ECO_2 (KSA)
Omri et al. (2014)	54 Countries (1990–2011)	Dynamic simultaneous equation method, GMM Arellano and Bond.	FDI ↔ ECO_2
Amin et al. (2020)	13 Asian (1985–2019)	Cointegration tests, FMOLS., Panel VECM	TO ↔ ECO_2 U + ECO_2, TO + ECO_2 U ↔ ECO_2
Anwar et al. (2020)	East Asia (1980–2017)	Panel data	U + ECO_2 TO + ECO_2
S. P. Nathaniel (2020)	Indonesia (1971–2014)	ARDL	U + ECO_2 LR: TO + ECO_2 SR: TO – ECO_2
Omri et al. (2015)	12 MENA countries (1990–2011)	Generalized method of moments (GMM)	TO→ ECO_2
S. Nathaniel and Khan (2020)	ASEAN (1990–2016)	Unit root tests, ointegration.	EG→TO
Adams et al. (2020)	19 Countries Sub-Saharan Africa (1980–2011)	Estimator IV-GMM	FDI- ECO_2
Ahmed et al. (2017)	ASEAN 8 (1985–2015)	Panel unit root tests, Panel cointegration test, Forecast: Innovative Accounting Approach (IAA)	EG → TO
Chandran and Tang (2013)	ASEAN 5 (1971–2008)	Cointegration, Granger causality	FDI ≠ ECO_2

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			FDI ↔ ECO_2 (Tha, Mal)
Pié et al. (2018)	30 Countries (1992–2012)	Bayesian framework	X – ECO_2 M + ECO_2
Akalpler and Hove (2019)	India (1971–2014)	ARDL	ECO_2 → X M → ECO_2 M → EG (-) M → EG (+)
Salehnia et al. (2020)	14 MENA Countries (2004–2016)	Panel quantile regression	FDI – ECO_2 TO + ECO_2 M + ECO_2 X + ECO_2
Al-Mulali and Sheau-Ting (2014)	189 Countries (1990–2011)	Panel fully modified OLS (FMOLS)	TO + ECO_2
F. Chen et al. (2021)	64 Countries (2001–2019)	Panel quantile regression	TO + ECO_2

Remark: ECO_2: CO_2 emissions, U: urbanization, EG: economic growth, X: export, M: import, FDI: foreign direct investment, TO: trade openness. SR are LR are short-run and long-run, respectively. "+" and "−" indicate positive and negative effect, respectively. "→" "↔" and "≠" indicate unidirectional, bidirectional, and independence relationships, respectively. "∩" indicates shaped U curve.

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3. Methodology

This study was conducted using a descriptive quantitative method. The data were obtained from the International Energy Agency in 2021 and the World Development Indicators (WDI) that were published by the World Bank in 2021. Furthermore, time series data were obtained from 1971 to 2019. This period was selected based on the consideration that the first UN Environmental Conference was conducted in Stockholm in 1971. The variables description is presented in Table 2.

Table 2. Variables Description.

Variable	Description	Unit	Source
CO_2 emissions (CO_2)	The residual CO2 that is discharged into the environment	Tonnes CO2/Terajoule	International Energy Agency, 2021
Economic growth (GDPC)	Gross Domestic Product per capita	IDR in constant price	World Bank
Urbanization (UD)	The percentage of people living in urban areas.	%	World Bank
Export (X)	The value of exports made by a country.	IDR in constant price	World Bank
Import (M)	The value of imports of goods to a country.	IDR in constant price	World Bank
Foreign direct investment (FDI)	Net inflow as the proportion of total Gross Domestic Product	%	World Bank

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Besides urbanization and foreign direct investment, which is taken as the proportion of total GDP, all variables are expressed in the form of logarithms to minimize the effect of heteroscedasticity (Maparu and Mazumder 2017). Table 3 shows a summary of the descriptive statistics of variables.

Table 3. Descriptive Statistics.

Variable	Maximum	Minimum	Mean	Std. Dev.	Observations

LCO^2	1.762	1.235	1.549	0.136	49
UD	55.985	17.338	36.176	12.588	49
LEG	7.607	6.864	7.247	0.209	49
LX	15.359	14.258	14.852	0.328	49
LM	15.342	13.771	14.777	0.423	49
FDI	4.241	−2.757	1.198	1.335	49

In this study, the analysis was conducted in different stages (Figure 1).

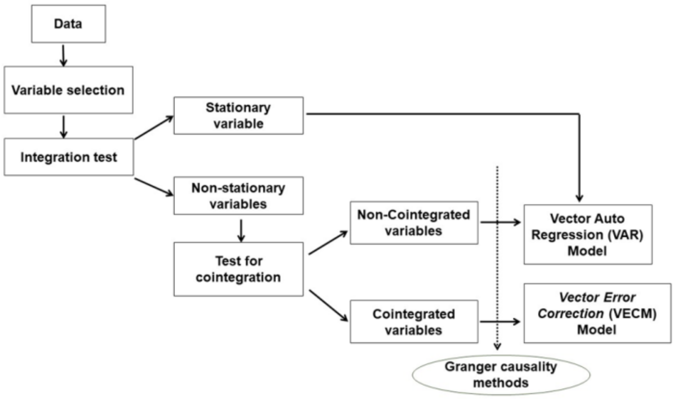

Figure 1. Test Stages in Granger Causality.

The first step is to use a preliminary statistical test to verify stationarities for all variables. This is conducted through the usual unit root method, which is known as the augmented Dickey–Fuller test (ADF). This step is important for two reasons: (1) The causality test is highly sensitive to serial stationarity, and (2) most of the time-series data for macroeconomic indicators are non-stationary. The ADF test is very popular for testing sequence integration of variables. Empirically, Equation (1) is represented as follows:

$$\Delta y_t = x_t b + \delta y_{t-1} + \sum_{i=1}^{m} a_1 \Delta y_{t-1} + \varepsilon_t \quad (1)$$

where y_t = time series to be tested, x_t = the selected exogenous regressor that contained constants and trends, a and b = the parameters that should be estimated, ε_t = the white noise error terms, m = the maximum lag length determined using Schwarz information and Akaike information criteria (SIC and AIC), and Δ = delta. According to the second step, when both series were integrated from the same order, the lag length was determined through the AIC and SIC, with the presence of cointegration also checked. Furthermore, the null hypothesis (H0: δ = 0) was tested against the alternative (Ha: δ < 0). When the null hypothesis is true, the existence of a unit root is confirmed, with the series observed as non-stationary. However, when the null hypothesis is rejected, stationary series are indicated.

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Based on this study, the cointegration test was carried out through the Johansen method by focusing on the statistical value of the trace and maximum Eigen analysis value. The vector error correction model (VECM) is used when variables are co-integrated. However, when not co-integrated, the vector auto regression (VAR) model is used. Therefore, the general model for the regression is shown as follows (Maparu and Mazumder 2017):

$$y_t = \sum_{i=1}^{p} \beta_i y_{t-i} + \gamma x_t + u_t \quad (2)$$

where, y_t = the vector of the non-stationary variable k I (1), x_t = the vector of the deterministic variable, β_i and γ = the parameters to be calculated, u_t = the innovation vector, and p = the VAR sequence.

According to the Granger causality test for equation (2), a variable (x) was stated to be a Granger causal to the other (y). This was observed when the lagging value of x increased the predictability of y, provided that other data were present. Moreover, the bivariate causality was divided into 3 categories, as follows: (1) Unidirectional: This causality was direct from x to y, when the coefficient on lagged x_t was significantly different from zero as a group. It was also directed from x to y, when y_t is the dependent variable and the coefficient on lagged y_t does not differ significantly from zero. The causality was also directed from x to y when x_t is the dependent variable. (2) Bidirectional: This indicated a relationship between x and y when the coefficient on the lagged x_t significantly differed from zero as a group. Moreover, it indicated a relationship, when y_t is the dependent variable. The coefficient on lagged y_t was significantly different from zero, when x_t is the dependent variable. (3) Independence: The causality occurred when the coefficients on x_t and y_t lagged were significantly different from zero in both equations.

If the variables are cointegrated, the vector error correction model (VECM) can be used instead of VAR. Equation (3) shows the general model for VECM.

$$\Delta y_t = \sum_{i=1}^{q} \beta_i y_{t-i} + \emptyset x_t + \gamma ECT_t + u_t \tag{3}$$

where, Δ is the first difference operator, β_i and $\emptyset$ = the parameters to be calculated, u_t = the white noise error terms, and q = the maximum lag length.

The vector error correction model (VECM) can be used for testing Granger causality between the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment. The empirical equation of VECM is presented as follow:

$$\begin{bmatrix} \Delta LCO^2{}_t \\ \Delta UD_t \\ \Delta LEG_t \\ \Delta LX_t \\ \Delta LM_t \\ \Delta FDI_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{j=1}^{L} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} & \beta_{35j} & \beta_{36j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} & \beta_{45j} & \beta_{46j} \\ \beta_{51j} & \beta_{52j} & \beta_{53j} & \beta_{54j} & \beta_{55j} & \beta_{56j} \\ \beta_{61j} & \beta_{62j} & \beta_{63j} & \beta_{64j} & \beta_{65j} & \beta_{66j} \end{bmatrix} \begin{bmatrix} \Delta LCO^2{}_{t-j} \\ \Delta UD_{t-j} \\ \Delta LEG_{t-j} \\ \Delta LX_{t-j} \\ \Delta LM_{t-j} \\ \Delta FDI_{t-j} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \tag{4}$$

where α and γ are the coefficients to be estimated and ECT_{t-1} is the lagged residual term derived from the long-run relationship. If γ is negative and significantly different from zero, it is a long-term interplay. L is the maximum lag length, Δ is the first difference operator, and ε is the error term.

Recall Equation (4). We can break it down into the following equations:

$$\Delta LCO^2{}_t = \alpha_1 + \sum_{j=1}^{L} \beta_{11j} \Delta LCO^2{}_{t-j} + \sum_{j=1}^{L} \beta_{12j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{13j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{14j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{15j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{16j} \Delta FDI_{t-j} + \gamma_1 ECT_{t-1} + \varepsilon_{1t} \tag{5}$$

$$\Delta UD_t = \alpha_2 + \textstyle\sum_{j=1}^{L} \beta_{21j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{22j} \Delta LCO^2{}_{t-j} + \sum_{j=1}^{L} \beta_{23j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{24j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{25j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{26j} \Delta FDI_{t-j} + \gamma_2 ECT_{t-1} + \varepsilon_{2t} \tag{6}$$

$$\Delta LEG_t = \alpha_3 + \textstyle\sum_{j=1}^{L} \beta_{31j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{32j} \Delta LCO^2{}_{t-j} + \sum_{j=1}^{L} \beta_{33j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{34j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{35j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{36j} \Delta FDI_{t-j} + \gamma_3 ECT_{t-1} + \varepsilon_{3t} \tag{7}$$

$$\Delta LX_t = \alpha_4 + \textstyle\sum_{j=1}^{L} \beta_{41j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{42j} \Delta LCO^2{}_{t-j} + \sum_{j=1}^{L} \beta_{43j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{44j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{45j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{46j} \Delta FDI_{t-j} + \gamma_4 ECT_{t-1} + \varepsilon_{4t} \tag{8}$$

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$$\Delta \text{LM}_t = \alpha_5 + \sum_{j=1}^{L} \beta_{51j}\, \Delta \text{LM}_{t-j} + \sum_{j=1}^{L} \beta_{52j}\, \Delta \text{LCO}^2{}_{t-j} + \sum_{j=1}^{L} \beta_{53j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{54j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{55j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{56j}\, \Delta \text{FDI}_{t-j} + \gamma_5 \text{ECT}_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \text{FDI}_t = \alpha_6 + \sum_{j=1}^{L} \beta_{61j}\, \Delta \text{FDI}_{t-j} + \sum_{j=1}^{L} \beta_{62j}\, \Delta \text{LCO}^2{}_{t-j} + \sum_{j=1}^{L} \beta_{63j}\, \Delta \text{UD}_{t-j} + \sum_{j=1}^{L} \beta_{64j}\, \Delta \text{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{65j}\, \Delta \text{LX}_{t-j} + \sum_{j=1}^{L} \beta_{66j}\, \Delta \text{LM}_{t-j} + \gamma_6 \text{ECT}_{t-1} + \varepsilon_{6t} \quad (10)$$

The long-term equilibrium is shown by the negative ECT coefficient. It indicates a correction of the variable movement towards its long-term equilibrium; hence, the coefficient should be negative. This indicates that the closer to zero the coefficient values are, the quicker the adjustment towards long-run equilibrium.

4. Results and Discussion

4.1. Empirical Results

Before examining cointegration between variables, we present an overview related to CO^2 emissions in Indonesia during the period 1971–2019. This is necessary to find out its role towards net zero emissions through the vector error correction model.

Figure 2 shows trends in CO^2 emissions that have occurred since 1971, tending to increase. It implies that significant growth in emissions has occurred since 1971, accompanied by increasing urbanization and economic growth (Figures 3 and 4). Prior to the economic crisis in 1998, an international agreement did not influence the reduction of CO^2 emissions in Indonesia. Carbon emissions constantly rose after the first United Nations Environmental Conference, which was conducted in Stockholm in 1971. Since 1998, a significant increase in economic activities, such as exports and imports (Figures 5 and 6), have led to relatively higher emissions. The Kyoto Protocol, which was signed in 1997, made the trend of carbon emissions fluctuate, as well as the Paris Agreement in 2015. It implies the influence of international agreement diplomacy on economic activities related to the reduction of CO^2 emissions. Figure 7 shows the volatility of FDI net inflows. Since the heaviest economic crisis in 1998, foreign direct investment has tended to increase. Global shocks had brought it down in 2008 and 2016, but it rose again at the end of 2019. This confirms that the interest of investors in Indonesia is still high.

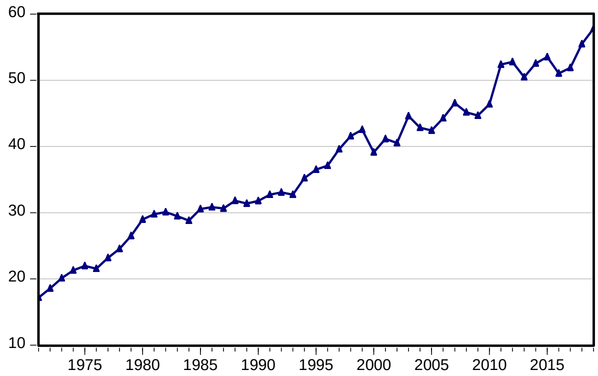

Figure 2. Time trend of CO^2 Emissions.

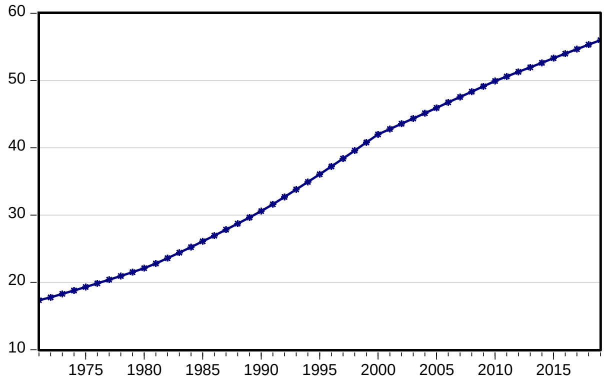

Figure 3. Time trend of Urbanization.

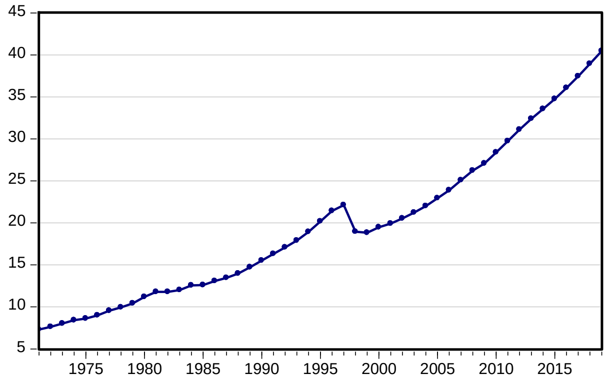

Figure 4. Time trend of Economic growth.

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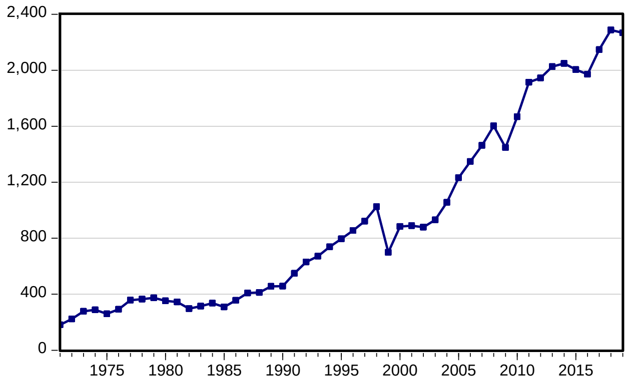

Figure 5. Time trend of Export.

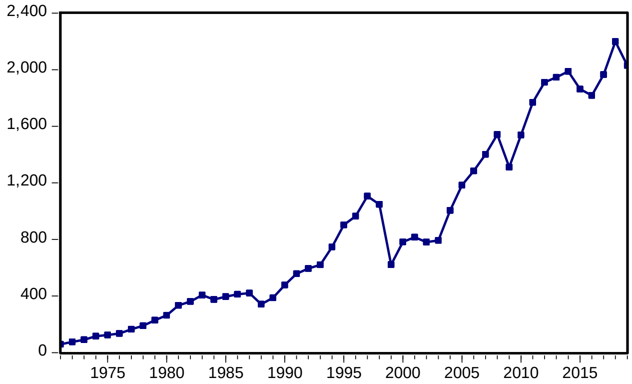

Figure 6. Time trend of Import.

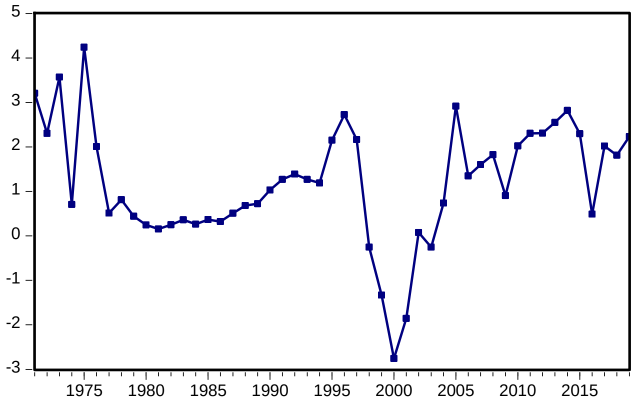

Figure 7. Time trend of Foreign Direct Investment.

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The dynamic causal relationship between CO_2 emissions, urbanization, economic growth, export, and import activities, as well as foreign direct investment, was assessed through several steps. Firstly, each variable containing the unit root was checked. Secondly, the test to determine whether there was a long-term cointegration relationship between the variables was conducted. Thirdly, the estimation of the VECM to deduce the Granger causal relationship between the variables was carried out. A summary of the results is shown in Table 4 based on the first stage, which is the unit root identification of each variable.

Table 4. Root Test of ADF-PP.

Variable	ADF		PP	
	t-Statistic	**Prob.**	**t-Statistic**	**Prob.**
Level				
LCO_2	−1.802599	0.3748	−2.454673	0.1329
UD	−1.697425	0.4258	0.198221	0.9697
LEG	−0.618192	0.8566	−0.606277	0.8593
LX	−0.630870	0.8536	−0.601572	0.8603
LM	−2.536889	0.1135	−2.592632	0.1016
FDI	−3.296863	0.0206	−3.348542	0.0181
First difference				
L CO_2	−5.806780	0.0000 *	−7.190028	0.0000 *
UD	−1.579417	0.4848	−1.648529	0.4502
LEG	−5.103162	0.0001 *	−5.072025	0.0001 *
LX	−8.107578	0.0000 *	−8.160933	0.0000 *
LM	−6.087550	0.0000 *	−6.087550	0.0000 *
FDI	−9.123195	0.0000 *	−9.067042	0.0000 *
Second difference				
UD	−6.02711	0.0000 *	−5.980405	0.0000 *

Remarks: * significant at the 1% level.

The first stage was the ADF unit root test, which showed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment were not stationary in the level integration analysis (Table 4). Furthermore, the first difference was conducted on all stationary variables I (1), except for the UD. This indicated that there was a difference in the level of stationarity within the UD variable, as the Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), Fisher–ADF, and Fisher–PP tests were carried out, respectively. The summary of the results is shown in Table 5. Based on the use of the Levin–Lin–Chu, Pesaran–Shin, and ADF–PP methods, the first difference root test showed that all results were stationary at I (1), due to the probability which was less than 5%. This also confirmed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment, were tested for cointegration.

Table 5. Group Unit Root Test.

Method	Level		First Different	
	Statistic	**Prob.**	**Statistic**	**Prob.**
Levin, Lin & Chu t *	−0.23198	0.4083	−7.51263	0.0000 *
Im, Pesaran and Shin W-stat	−0.50251	0.3077	−12.0491	0.0000 *
ADF-Fisher Chi-square	15.9249	0.1947	133.866	0.0000 *
PP-Fisher Chi-square	15.4927	0.2156	135.685	0.0000 *

Remarks: * significant at the 1% level. Number of observations 276.

The optimal lag length was determined based on the Akaike information criterion (AIC). According to the determination of the most optimal lag, the highest LR and low AIC, HQIC, and SBIC values were observed. The results showed the optimal lag length used was two, through the consideration of the lowest AIC value. Subsequently, a stability test was conducted to determine the usable model (VAR or VECM). The results also showed the variables to be used met the stability criteria, as the modulus values were less than one; hence, the VAR or VECM was used.

After passing the stability analysis, the cointegration test was conducted. Furthermore, the Johansen cointegration test was found to be based on the linear determinism assumption (intercept and trend). A long-term balance was observed when the trace or Max-Eigen values were more than the critical value of 5%. Therefore, the results of the Johansen cointegration test based on Trace and Max-Eigen statistics are summarized in Table 6.

Table 6. Johansen Cointegration Test.

Hypothesis	Eigenvalue	Trace-Test		Max-Eigen Test	
		Statistic	ρ Value	Statistic	ρ Value
None	0.731063	136.8953	0.0000 *	60.41077	0.0001 *
At most 1	0.504075	76.48456	0.0133 **	32.26119	0.0770
At most 2	0.361128	44.22337	0.1054	20.61038	0.3004
At most 3	0.242559	23.61299	0.2173	12.77925	0.4727
At most 4	0.159968	10.83374	0.2219	8.018521	0.3768
At most 5	0.059365	2.815217	0.0934	2.815217	0.0934

Remark: * Significant at the 1% level; ** Significant at the 5% level.

The null hypothesis of Johansen's test stated that cointegration occurred when at least one analysis was cointegrated. The null hypothesis was accepted based on the results, which showed trace and Max-Eigen test values of two and one cointegrations at the 0.05 level, respectively. This indicated that there was cointegration between variables, as CO^2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment, had a long-term relationship within the period of 1971 to 2019 in Indonesia. These variables were also eligible for the VEC framework.

Based on the use of VECM, the causality source was identified from the significance test that was conducted for the coefficient of the independent variable. According to the short-term causality, the Granger causality/block exogeneity Wald tests were used to determine the nullity of the parameters associated with the independent variable in each VECM equation, through the $\chi 2$-Wald statistic. However, causality in the long term was tested by the significance of the adjustment speed. The t-statistic of the ECT coefficient that showed a long-term causal effect was also used.

Table 7 shows three out of six vectors had a negative value of ECT-1, but only Equation (5) was statistically significant at a 1% significance degree. This means only CO^2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurs from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short-term. Likewise, imports into urbanization and economic growth had a one-way relationship to exports and imports (Table 7).

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Table 7. Granger Causality/Block Exogeneity Wald Tests.

Dependent Variable	Short Run						Long Run	
	ΔL(CO_2)	ΔUD	ΔL(EG)	ΔL(X)	ΔL(M)	ΔFDI	Coefficient	*t*-Test
ΔL(CO_2)	-	18.72401 (0.0001) *	6.126103 (0.0467) **	1.802927 (0.406)	10.50891 (0.0052) *	31.76471 (0.000) *	−0.863939	−7.31613 *
ΔUD	0.885313 (0.6423)	-	0.894056 (0.6395)	1.505821 (0.471)	9.9198 (0.007) *	0.759596 (0.684)	0.62141	1.15879
ΔL(EG)	0.020633 (0.9897)	3.397833 (0.1829)	-	0.255068 (0.8803)	0.241267 (0.8864)	1.068797 (0.586)	−0.126233	−0.80081
ΔL(X)	2.835755 (0.2422)	2.549941 (0.2794)	16.40749 (0.0003) *	-	0.363593 (0.8338)	0.042006 (0.9792)	0.518394	1.31906
ΔL(M)	2.0033835 (0.3673)	1.69154 (0.4292)	30.15772 (0.0000) *	2.537506 (0.2812)	-	0.027722 (0.9862)	−0.017462	−0.03758
ΔFDI	2.94009 (0.2299)	4.537871 (0.1034)	2.024757 (0.3634)	1.783195 (0.4100)	3.849635 (0.1459)	-	11.73753	1.06675

Remark: * Significant at the 1% level; ** Significant at the 5% level; *** Significant at the 10% level.

4.2. Impulse Response

Impulse response CO_2 emissions to urbanization showed that the urban density was included in the counter-urbanization phase in the short-term. This phase is characterized by a decrease in the environmental, physical, and socio-economic carrying capacity of the population in the larger metropolitan area (Sarungu, 2001). The high level of urbanization can result in rapid population growth that leads to agglomeration and will be followed by efforts of people to fulfill their needs. Due to the speed and scale of escalation in these cities, they can induce great pressure on the environment and pose environmental degradation or threats to sustainable development (Cohen 2006). This result is in line with Agung PS et al. (2017) and Liang et al. (2019). In the long-term, CO_2 emissions will decrease along with the awareness of city dwellers about the importance of health and quality of life. This is consistent with the negative response of CO_2 emissions to urban density (Figure 8b). Therefore, urbanization can be directed to reduce CO_2 emissions by using the potential spillover of technology and high levels of education. This is consistent with Liu and Liu (2019), Hassan et al. (2020), and S. Wang et al. (2020).

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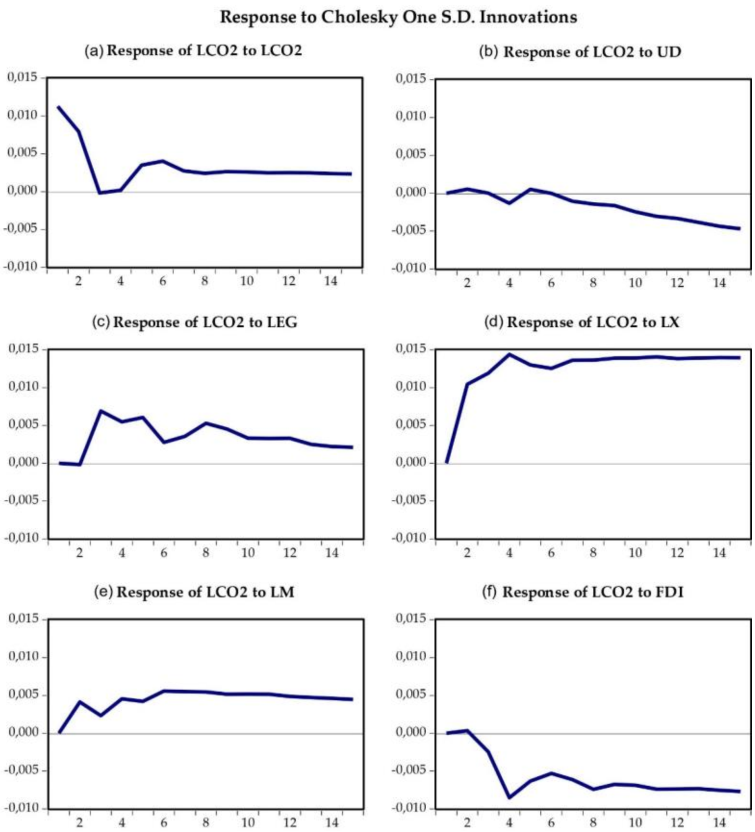

Figure 8. Impulse response functions.

Assuming FDI changes, the response of CO^2 emissions was positive in the short run, but was negative in the third year, reaching its lowest point in the fourth year, and subsequently tends to move steadily (Figure 8f). The positive response of CO^2 emissions during the shock in FDI was consistent with the VECM estimation in this study. It also showed an increase in FDI in the long run, leading to environmentally oriented investment. This is in line with Adams et al. (2020), Salehnia et al. (2020), and Chen et al. (2021). This is a great target that developing countries should build upon in order to realize the halo pollution hypothesis, along with the increasing FDI values every year. The responses of CO^2 emissions to export and import economic activities were positive. A shock to exports will increase CO^2 emissions sharply until the fourth year, and subsequently the changes tend to be stable in the long term (Figure 8d). The same pattern was shown by imports. Although the response to CO^2 emissions was smaller than the shock to exports, it was also positive to changes in imports (Figure 8e). This is a formidable challenge for net-zero carbon. Actually, the policy of goods or commodities received from the rest of the world for Indonesian consumption has led to the procurement of cordial environmental commodities which minimizes the occurrence of CO^2 emissions. The Government of Indonesia issued Statute Law Number 32 (UU No 32) in 2009 concerning Environmental Protection and Management (UU PPLH) as well as Statute Law Number 18 (UU No 18) in 2008

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concerning Waste Management (UU Waste Management). It was subsequently strengthened by the stipulation of Statute Law Number 7 (UU No 7) in 2014 concerning Trade, specifically Article 50 paragraph (1) and (2) which states that all goods can be exported or imported, except those prohibited, restricted, or otherwise stipulated by law. The newest implementation is regulated in Government Regulation No. 22 (PP No 22) in 2021 concerning the implementation of environmental protection and management. The climate change emergency at COP26 is time-bound, making net zero carbon policy mandatory for companies. Based on the results of variance decomposition (Table 8), the largest contribution to emissions comes from export activities. Therefore, failure to immediately adapt to a net zero carbon policy can lead to loss of global market share.

4.3. Variance Decomposition

Initially, the largest contribution to CO^2 emissions in the short term is the variance in the variable itself, but its contribution decreased afterward. The largest contribution was taken over by exports. Initially, it contributed only 34%, but increased continuously to become the largest at the end of the period (Table 8). Economic growth, FDI, urbanization, and imports also showed an increasing trend of contributions.

Table 8. Variance Decomposition of L CO^2.

Period	S.E.	Illustrated by Variable (%)					
		LCO^2	UD	LEG	LX	LM	FDI
1	0.01126	100	0	0	0	0	0
2	0.01778	60.0086	0.08991	0.00916	34.4567	5.39887	0.03685
3	0.02273	36.7204	0.05502	9.20014	48.4918	4.34863	1.18405
4	0.02912	22.3715	0.24277	9.14684	53.8769	5.08307	9.27894
5	0.03352	17.9672	0.20705	10.1653	55.6899	5.41679	10.5537
6	0.03693	15.9996	0.17066	8.9383	57.3913	6.7383	10.7619
7	0.04047	13.7793	0.21075	8.2149	59.0947	7.45419	11.2462
8	0.04409	11.9095	0.28457	8.34995	59.3394	7.81342	12.3031
9	0.04731	10.6518	0.36451	8.16321	60.1271	7.9719	12.7215
10	0.05029	9.69206	0.56157	7.65746	60.8523	8.11226	13.1244
11	0.05324	8.86569	0.83062	7.21289	61.2709	8.17552	13.6444
12	0.05596	8.22208	1.10796	6.87468	61.5566	8.15348	14.0852
13	0.05855	7.68971	1.4459	6.46236	61.8715	8.09846	14.4321
14	0.06108	7.21843	1.83961	6.06841	62.0817	8.00712	14.7847
15	0.06353	6.80859	2.24968	5.71815	62.1948	7.8946	15.1342

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The biggest contribution from export activities to CO^2 emissions should be the main notice related to Indonesia's commitment to achieving net-zero carbon by 2070. It should also be noted that international agreements to reduce CO^2 emissions were more or less efficient, but on the other hand, it has reduced the competitiveness and exports of several countries (C. H. Wang et al. 2019). Some countries in Asia, Europe, and America have implemented climate change mitigation programs to reduce emissions, which influences trading regulations. Requirements are set to the product; hence, it can be accepted globally by fulfilling sustainability requirements. For example, low-emission industrial product companies do not carry out deportations or execute forest conservation policies.

Foreign direct investment contributes to economic growth (Omri et al. 2014). It recognizes that investment, advanced technology, and knowledge can be transferred from industrialized countries to developing countries as an important asset to increase economic growth (Raz et al. 2012). Therefore, FDI can accelerate the speed of general purpose technologies (GPT) as the engine of growth. However, in some countries, the existence of this investment turns out to provide negative externalities to the environment, thereby proving the pollution haven hypothesis (Aliyu 2005; Aljawareen and Saddam 2017). The results showed foreign direct investment contributed significantly to CO^2 emissions. Economic agents should anticipate such factors carefully in order to remain competitive in

the global economy due to climate change. For example, the European Union makes policies regarding sanitary and phytosanitary goods to protect human and animal health, as well as environmental requirements (sustainable forest certificates and ecolabels, origin of products) for wood commodities. Other requirements, such as health and safety (free of fluorocarbon and formaldehyde emissions) and expensive costs are also not hard to manage. These should be borne by Indonesian entrepreneurs. Similarly, the Japanese government has a standard for wood products (Japan Agricultural Standard, JAS) and other export destination countries. Therefore, the right strategy is needed to synergize between economic growth air quality. Although economic activities should be carried out, it needs to be balanced in order to achieve net zero carbon.

5. Conclusions

This study aims to analyze the pattern of urbanization, economic growth, exports, imports, foreign direct investment, and CO^2 emissions. It also proved whether the halo or haven pollution hypotheses existed in Indonesia from 1971 to 2019. According to the results, CO^2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short term. Likewise, imports into urbanization and economic growth indicated a one-way relationship to exports and imports. This consequently strengthened the IPAL model by Dietz and Rosa (1997), which stated that population, income, and technology are considered as the main drivers of environmental impact.

The pollution haven hypothesis exists in Indonesia, and FDI had a one-way interplay with CO^2 emissions. The government should regulate air pollution by conditioning urbanization to be environmentally friendly through building several green open spaces and public transportation that uses accommodative fuel or renewable energy. Gradually, capital should be directed to investments that promote the economy to thrive. Foreign investment is used as a pillar to support the realization of a green urban development model. This is achieved by limiting negative environmental externalities through procurement and physical investment, particularly in power generation, transportation, and manufacturing industries.

Countries that are committed to climate change prevention in the Paris Agreement should compile long-term development plans that are integrated with strategies to reduce the amount of greenhouse gas emissions. In other words, the target for reducing emissions in its implementation needs to be coherent with several existing policies, specifically Indonesia's ambition to escape from the middle-income trap. The toughest challenge for the country is the use of coal energy sources. The transfer of coal plants to renewable energy in 2040 requires the support of international cooperation, technology, economic feasibility, and international funding to assist the energy transition. Therefore, the formation of a healthy and prosperous state ecosystem can be achieved when there is collaboration from all economic agents.

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Informed Consent Statement: Not applicable

Data Availability Statement: The corresponding author [D.M.N] of the present work is available for any information about data availability.

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Conflicts of Interest: The authors declare no conflicts of interest.

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CO^2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon

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Abstract: This study aims to analyze the nexus between CO^2 emissions, urbanization, and economic activity, as well as identify whether the pollution haven hypothesis is proven in Indonesia. It utilized time series data of Indonesia during the 1971–2019 period. Furthermore, the vector error correction model (VECM) was used to determine the long-run and short-run interplay using cointegration and Granger causality approaches. The empirical results showed the pollution haven hypothesis occurred in Indonesia. A long-term relationship with CO^2 emissions was observed from the model. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short term. It was concluded that the achievement of the Paris Agreement will be successful when the committed countries are courageous in transforming their economy. However, major adjustments are needed, where all parties need to have the same vision towards net zero carbon.

Keywords: CO2 emissions; economic activities; urbanization; net zero carbon

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1. Introduction

The 2021 UN climate change conference (COP26) was held in Glasgow, Scotland, on 31 October–12 November 2021. This event is an extension of the Paris Agreement and serves as a reminder that a big agenda needs to be immediately carried out to address climate change due to human activities. Several countries are challenged with the trade-off between economic growth and environmental degradation. The environmental Kuznets curve (EKC) hypothesis explains an inverted U-shaped relationship between economic growth and environmental degradation. This means environmental pressure increases in the early stages of economic growth due to the increased release of pollutants as well as extensive and intensive exploitation of natural resources associated with greater use of production (Grossman and Krueger 1991; Özokcu and Özdemir 2017; Shahbaz et al. 2019; Rahman et al. 2020).

Also, it is found that the efforts to reach a turning point are challenging in terms of improving environmental quality. CO^2 emissions are increased when economic development activities are high. This indicates that the quicker the regional economic growth, the worse the air pollution (Hossain 2011; Ben Abdallah et al. 2013; Hasanov et al. 2018).

Before the pandemic, Indonesia was ranked as one of the world's emerging markets at the end of 2019. In fact, the economic growth has been reasonably consistent at about 5.1% in 2019 due to the strong trust of foreign investors. However, in 2015, Indonesia became the fourth-largest emitter of greenhouse gases, which is a major source of concern. According to the World Bank Indicators released in 2020, there was an increase in CO^2 emissions of 4.4%/year on average between 2001 and 2018. The highest increase and lowest decrease in the emissions occurred in 2011 and 2013 at 14.8% and 7.5%, respectively.

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Furthermore, the economic performance increased by 0.1–0.28 points, but the air quality decreased by more than 10%, a condition that will be a threat to Indonesia. According to the World Bank, about 220 million Indonesians will live in cities and towns by 2045. Consequently, the high population density will lead to accelerated economic activity in the region. This is in line with Liang et al. (2019), who stated that rapid urbanization will promote social and economic development but raise some environmental pollution problems (Camagni et al. 1998). This implies that environmental quality will deteriorate as more resources are used to promote economic activity.

COP26 provides momentum for the nation to prepare risk mitigation in international trade with the application of levies on carbon emissions. Empirical studies related to the influence of international trade in Indonesia showed different results. Bhattacharya et al. (2019) found that there was no significant effect between trade openness and CO^2 emissions. Meanwhile, Nathaniel (2020) stated that Indonesian trade can reduce natural CO^2 emissions in the short-term but exacerbate environmental degradation in the long-term. The open economic system has contributed to CO^2 emissions (F. Chen et al. 2021); therefore, this study focused more specifically on the relationship between exports and imports of CO^2emissions due to the carbon emission tax policy on international trade. In addition, it harbors suspicion about the two responses that are different from CO^2 emissions; hence, separate identification is needed to determine the final policy. Studies of exports and imports have provided different results. Exports promote an increase in emissions (Salehnia et al. 2020) and also improve environmental quality (Hasanov et al. 2018; Pié et al. 2018). The result of import activities showed that imports cause environmental degradation (Hasanov et al. 2018; Pié et al. 2018; Salehnia et al. 2020), while Aljawareen and Saddam (2017) stated that it is a stimulus for improving air quality.

In advance, the existence of the pollution haven hypothesis needs to be tested. Salahuddin et al. (2019) used the link between trade openness induced by globalization to prove the pollution haven hypothesis. Meanwhile, this study examines whether foreign direct investment results in increased CO^2 emissions. The reinforcing reason is that Indonesia has great potential for foreign investment. According to the United Nations Conference on Trade and Development (UNCTAD), Indonesia is among the top 20 developing countries that were the destination for FDI globally in 2017 and 2018. Hence, the relationship between investment and the environment in these countries can be examined to prove the pollution haven hypothesis. Based on previous studies, there is a two-way relationship between FDI and CO^2 emissions (Tang and Tan 2015; Omri et al. 2014). The connection between CO^2 emissions and FDI will be beneficial to the environment when the pollution haven hypothesis is not discovered (Z. Chen et al. 2021). Meanwhile, Omri et al. (2014) stated that FDI had a unidirectional relationship and a positive effect on CO^2 emissions in Qatar. Kizilkaya (2017) discovered that foreign direct investment was ineffective on CO^2 emissions in Turkey. Therefore, this study aims to analyze the interplay of urbanization, economic growth, exports, imports, foreign direct investment, and CO^2 emissions. It also proves whether the pollution halo or haven hypotheses existed in Indonesia from 1971 to 2019. It is of prominent importance to developing countries or those highly dependent on international trade, related to the global commitment to reducing carbon emissions and the transition process toward a low-carbon country.

The theoretical basis and previous empirical studies are presented after the background of the study to comprehend the relationship between urbanization, economic growth, export, import, foreign direct investment, and CO^2 emissions. Afterward, the methods section provides an overview of the variables used, and the stages carried out. The next section presents the results, which are subsequently deepened by the discussion, as well as the conclusions and policy implications.

2. Literature Review

The relationship between urbanization and environmental quality is founded on the concept of an urban area in which demand-driven activities center on cost reduction. This

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is due to its closeness to other regions with similar proximity, endowment resources, and high population density. In addition, because of this association, people are able to rationally relocate to urban areas. Urbanization is formed through socio-economic development. According to Pernia et al. (1983), population growth is often higher in rural areas than urban areas. This indicates that there is a direct demographic effect, which involves reducing the proportion of urban areas. It was also stated that population growth hampers economic development. This indicates that urbanization is either influenced directly or indirectly by socio-economic development, through population growth. Meanwhile, Firebaugh (1979) stated that it is influenced directly and indirectly by the deterioration of rural conditions and economic development, as well as previous urbanization, respectively. Hence, urbanization theory should consider the conditions in rural and urban areas because it is applied to both developed and developing countries.

The migration of people to urban areas is carried out through different phases of the urbanization process as follows (Sarungu 2001). Firstly, there is agrarian urbanization, which entails innovation in agricultural technology application and leads to an increase in assertive productivity. Secondly, there is urbanization in industrialized metropolitan areas. It is characterized by an increasing concentration of population and economic activity in the vicinity of major cities, as well as substantial infrastructure investment to facilitate efficient export and import operations (Turok and McGranahan 2013). Thirdly, in a growing metropolitan area, there is a postindustrial non-metropolitan counter urbanization, which is characterized by a reduction in the population's physical and socioeconomic capacity.

The findings of empirical studies showed different results. Urbanization and pollution have bidirectional causality (Santillán-Salgado et al. 2020; Nosheen et al. 2020; Salahuddin et al. 2019; Amin et al. 2020; Abbasi et al. 2020;), while there is a one-way causality between urbanization and CO^2 (Ponce and Alvarado 2019; Bashir et al. 2021). Specifically, several empirical studies were conducted to determine the process that occurs in post-industrial non-metropolitan counter-urbanization. Urban regions, road area per capita, and GDP were found to have negative effects on CO^2 emissions (Qiu et al. 2019). Therefore, it needs to be controlled with careful planning and mitigation of CO^2 emissions (Yang et al. 2015; Hassan et al. 2020) because emissions and urbanization have a relationship (Santillán-Salgado et al. 2020).

Previous studies showed an inverted U-shaped relationship between economic growth and environmental degradation which is in line with the environmental Kuznets curve (EKC) hypothesis (Borhan et al. 2012; Lin and Zhu 2018; Hanif 2018; Tang and Tan 2015; dan C. H. Wang et al. 2019). An initial study by Grossman and Krueger (1991) and Tanger et al. (2011) reported the inverse relationship between CO^2 emissions and economic growth. The interesting outcome was presented by Hossain (2011) and Hossain (2012), which stated that several literatures had failed to establish an inverse U relationship with the real-life data. Particularly in developed and developing countries, the studies that examined the causal relationship between energy consumption and growth produced three different results. Other studies reportedly discovered two-way causation, as well as unidirectional causes and causality direction from output growth to energy consumption.

Economists also conducted studies on the relationship between FDI and economic growth. Externalities were transferred from industrialized to developing countries, based on the assumption that FDI is an important asset to boost greater development. According to developing countries, the investment served as a means of transferring factors, due to the accelerating pace of general purpose technologies (GPT), while introducing advanced technology and science. This means the countries exploited these factors as assets to increase economic growth. Furthermore, FDI defines economic openness from a financial standpoint, which has been proven to promote economic growth, although this has not been shown in the United States (Omri et al. 2015). The consequence of this openness is the emergence of negative externalities. The pollution haven hypothesis was developed from the studies of Copeland and Taylor (1994) and Chen et al. (2021). Based on this hypothesis, three dimensions (Aliyu 2005) were observed. Firstly, heavily polluting enterprises relocated from industrialized to developing countries, where strict environmental regulations were not enforced. Global free trade, on the other hand, has increased industrial and polluting activities by relocating to nations with weak environmental policies. Secondly, the transfer of hazardous waste from developed to developing countries (industrial production and nuclear energy). This issue was also the subject of the Basle Convention on hazardous waste. Thirdly, multinational companies involved in the production of petroleum and its products, as well as lumber and other forest resources, including the extraction of non-renewable natural resources in developing countries without control. These factors are related to conscious environmental policy decisions and how they impact the environment, production, and future trade. However, the pollution haven hypothesis has two empirical consequences, namely (1) FDI outflows in developed countries are positively correlated with environmental policy tightening, and (2) Pollution in developing countries is positively correlated with the inflows of FDI. The existence of foreign investment brings technological efficiency compared to those within the country (Balogh and Jámbor 2017; Adams et al. 2020; dan Salehnia et al. 2020). In addition, Aljawareen and Saddam (2017) showed that FDI had a positive interplay with CO^2 emissions in Qatar. The selected studies about the pattern of CO^2 emissions, urbanization, and economic activities are summarized in Table 1.

Table 1. Literature review of pattern of CO2 emissions, urbanization, and economic activities.

Authors	Country/Region (Periods)	Technique Analysis	Findings
	Economy Growth and CO^2 emissions		
Rahman et al. (2020)	5 South Asian Countries (1990–2017)	Granger causality, VECM FMOLS, DOLS, generalized method of moments (GMM)	ECO^2 + EG EG ↔ ECO^2
C. H. Wang et al. (2019)	5 Countries: Germany, Italy, India, Taiwan and Japan (1950–2010)	*Rolling regression*	EG ∩ ECO^2
Vo et al. (2019)	ASEAN 5 (1971–2014)	Granger causality, FMOLS, DOLS	EG → ECO^2
Abbasi et al. (2020)	8 Asia Countries (1982–2017)	Granger causality.	EG ≠ E$CO^2$2
Chikaraishi et al. (2015)	140 Countries (1980–2008)	Laten STIRPAT model	EG − ECO^2
(Batool et al. (2021)	ASEAN 5 (1980–2018)	Granger causality, VECM	EG + ECO^2 EG ≠ ECO^2 (Ind, Mal) LR: EG ↔ ECO^2 (Ind, Tha) SR: EG → ECO^2 (Phi, Sgp)
Joshua et al. (2020)	South Africa	ARDL	EG + ECO^2 EG → ECO^2
Phong et al. (2018)	Vietnam (1985–2015)	ARDL	EG + ECO^2
Bashir et al. (2019)	Indonesia (1985–2017)	VECM	EG ≠ ECO^2,
	Urbanization and CO^2 emissions		
Salahuddin et al. (2019)	South Africa (1980–2017)	Unit root tests (Zivot and Andrews single, dan Bai dan Perron), cointegration, ARDL	U ↔ ECO^2
Al-Mulali et al. (2013)	MENA Countries (1980–2009)	Pedroni's cointegration, panel Granger causality	U ↔ ECO^2 U + ECO^2
Hanif (2018)	34 Countries in Africa (1995–2015)	System generalized method of moment (GMM)	U + ECO^2
Adedoyin and Bekun (2020)	7 Countries (1995–2014)	Panel VAR approach, FMOLS, pooled mean group–ARDL	U ↔ ECO^2

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H. S. Ali et al. (2017)	Singapore (1970–2015)	ARDL	U – ECO_2
R. Ali et al. (2019)	Pakistan (1972–2014)	ARDL, VECM	U + ECO_2 U → ECO_2
Bekhet and Othman (2017)	Malaysia (1971–2015)	VECM, Granger causality	LR: U ↔ ECO_2 , Inv. Domestic ↔ E CO_2 SR: U → E CO_2, U → EG, Inv. Domestic → EG
Martínez-Zarzoso and Maruotti (2011)	Developing countries (1975–2003)	LSDVC, GMM methods	U ∩ ECO_2
Akorede and Afroz (2020)	Nigeria (1970–2017)	Causality tests, ARDL	U – ECO_2
Lin and Zhu (2018)	282 Cities in China (2012)	Bayesian model average	U – ECO_2
Ergas et al. (2016)	USA (2002–2007)	*A hybrid panel model*	U – ECO_2
Borhan et al. (2012)	8 East Asia	Simultaneous equation	ECO_2-U
Dong et al. (2019)	14 Countries maju	Two fixed-effect panel threshold models	SR: U ≠ECO_2 Middle Run : U – ECO_2
Economic Activities and CO_2 emissions			
Kizilkaya (2017)	Turkey (1970–2014)	ARDL	FDI ≠ ECO_2
Tang and Tan (2015)	Vietnam (1976–2009)	Cointegration, Granger causality	FDI ↔ ECO_2
Hasanov et al. (2018)	Azerbaijan, Bahrain, Kuwait, Oman, Qatar, Russia, Saudi Arabia, United Arab Emirates (UAE) and Venezuela (1995–2013)	PDOLS, PFMOLS, PMG methods, panel ECM	X – ECO_2 M + ECO_2
Aljawareen and Saddam (2017)	6 GCC Countries (1998–2008)	Panel data	FDI + ECO_2 (Qatar) M – ECO_2 (KSA)
Omri et al. (2014)	54 Countries (1990–2011)	Dynamic simultaneous equation method, GMM Arellano and Bond.	FDI ↔ ECO_2
Amin et al. (2020)	13 Asian (1985–2019)	Cointegration tests, FMOLS., Panel VECM	TO ↔ ECO_2 U + ECO_2, TO + ECO_2 U ↔ ECO_2
Anwar et al. (2020)	East Asia (1980–2017)	Panel data	U + ECO_2 TO + ECO_2
S. P. Nathaniel (2020)	Indonesia (1971–2014)	ARDL	U + ECO_2 LR: TO + ECO_2 SR: TO – ECO_2
Omri et al. (2015)	12 MENA countries (1990–2011)	Generalized method of moments (GMM)	TO→ ECO_2
S. Nathaniel and Khan (2020)	ASEAN (1990–2016)	Unit root tests, ointegration.	EG→TO
Adams et al. (2020)	19 Countries Sub-Saharan Africa (1980–2011)	Estimator IV-GMM	FDI- ECO_2
Ahmed et al. (2017)	ASEAN 8 (1985–2015)	Panel unit root tests, Panel cointegration test, Forecast: Innovative Accounting Approach (IAA)	EG → TO
Chandran and Tang (2013)	ASEAN 5 (1971–2008)	Cointegration, Granger causality	FDI ≠ ECO_2 FDI ↔ ECO_2 (Tha, Mal)
Pié et al. (2018)	30 Countries (1992–2012)	Bayesian framework	X – ECO_2 M + ECO_2

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Akalpler and Hove (2019)	India (1971–2014)	ARDL	$ECO^2 \rightarrow X$ $M \rightarrow ECO^2$ $M \rightarrow EG$ (-) $M \rightarrow EG$ (+)
Salehnia et al. (2020)	14 MENA Countries (2004–2016)	Panel quantile regression	FDI – ECO^2 TO + ECO^2 M + ECO^2 X + ECO^2
Al-Mulali and Sheau-Ting (2014)	189 Countries (1990–2011)	Panel fully modified OLS (FMOLS)	TO + ECO^2
F. Chen et al. (2021)	64 Countries (2001–2019)	Panel quantile regression	TO + ECO^2

Remark: ECO^2: CO^2 emissions, U: urbanization, EG: economic growth, X: export, M: import, FDI: foreign direct investment, TO: trade openness. SR are LR are short-run and long-run, respectively. "+" and "−" indicate positive and negative effect, respectively. "→" "↔" and "≠" indicate unidirectional, bidirectional, and independence relationships, respectively. "∩" indicates shaped U curve.

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3. Methodology

This study was conducted using a descriptive quantitative method. The data were obtained from the International Energy Agency in 2021 and the World Development Indicators (WDI) that were published by the World Bank in 2021. Furthermore, time series data were obtained from 1971 to 2019. This period was selected based on the consideration that the first UN Environmental Conference was conducted in Stockholm in 1971. The variables description is presented in Table 2.

Table 2. Variables Description.

Variable	Description	Unit	Source
CO^2 emissions (CO^2)	The residual CO2 that is discharged into the environment	Tonnes CO2/Terajoule	International Energy Agency, 2021
Economic growth (GDPC)	Gross Domestic Product per capita	IDR in constant price	World Bank
Urbanization (UD)	The percentage of people living in urban areas.	%	World Bank
Export (X)	The value of exports made by a country.	IDR in constant price	World Bank
Import (M)	The value of imports of goods to a country.	IDR in constant price	World Bank
Foreign direct investment (FDI)	Net inflow as the proportion of total Gross Domestic Product	%	World Bank

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Besides urbanization and foreign direct investment, which is taken as the proportion of total GDP, all variables are expressed in the form of logarithms to minimize the effect of heteroscedasticity (Maparu and Mazumder 2017). Table 3 shows a summary of the descriptive statistics of variables.

Table 3. Descriptive Statistics.

Variable	Maximum	Minimum	Mean	Std. Dev.	Observations
LCO^2	1.762	1.235	1.549	0.136	49
UD	55.985	17.338	36.176	12.588	49
LEG	7.607	6.864	7.247	0.209	49
LX	15.359	14.258	14.852	0.328	49

LM	15.342	13.771	14.777	0.423	49
FDI	4.241	−2.757	1.198	1.335	49

In this study, the analysis was conducted in different stages (Figure 1).

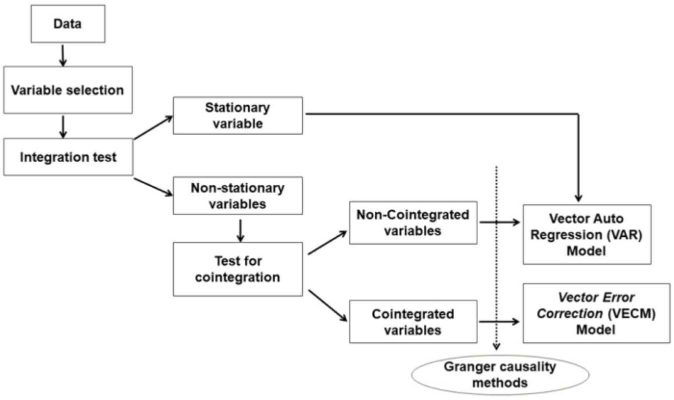

Figure 1. Test Stages in Granger Causality.

The first step is to use a preliminary statistical test to verify stationarities for all variables. This is conducted through the usual unit root method, which is known as the augmented Dickey–Fuller test (ADF). This step is important for two reasons: (1) The causality test is highly sensitive to serial stationarity, and (2) most of the time-series data for macroeconomic indicators are non-stationary. The ADF test is very popular for testing sequence integration of variables. Empirically, Equation (1) is represented as follows:

$$\Delta y_t = x_t b + \delta y_{t-1} + \sum_{i=1}^{m} a_1 \Delta y_{t-1} + \varepsilon_t \quad (1)$$

where y_t = time series to be tested, x_t = the selected exogenous regressor that contained constants and trends, a and b = the parameters that should be estimated, ε_t = the white noise error terms, m = the maximum lag length determined using Schwarz information and Akaike information criteria (SIC and AIC), and Δ = delta. According to the second step, when both series were integrated from the same order, the lag length was determined through the AIC and SIC, with the presence of cointegration also checked. Furthermore, the null hypothesis (H0: δ = 0) was tested against the alternative (Ha: δ < 0). When the null hypothesis is true, the existence of a unit root is confirmed, with the series observed as non-stationary. However, when the null hypothesis is rejected, stationary series are indicated.

Based on this study, the cointegration test was carried out through the Johansen method by focusing on the statistical value of the trace and maximum Eigen analysis value. The vector error correction model (VECM) is used when variables are co-integrated. However, when not co-integrated, the vector auto regression (VAR) model is used. Therefore, the general model for the regression is shown as follows (Maparu and Mazumder 2017):

$$y_t = \sum_{i=1}^{p} \beta_i y_{t-i} + \gamma x_t + u_t \quad (2)$$

where, y_t = the vector of the non-stationary variable k I (1), x_t = the vector of the deterministic variable, β_i and γ = the parameters to be calculated, u_t = the innovation vector, and p = the VAR sequence.

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According to the Granger causality test for equation (2), a variable (x) was stated to be a Granger causal to the other (y). This was observed when the lagging value of x increased the predictability of y, provided that other data were present. Moreover, the bivariate causality was divided into 3 categories, as follows: (1) Unidirectional: This causality was direct from x to y, when the coefficient on lagged x_t was significantly different from zero as a group. It was also directed from x to y, when y_t is the dependent variable and the coefficient on lagged y_t does not differ significantly from zero. The causality was also directed from x to y when x_t is the dependent variable. (2) Bidirectional: This indicated a relationship between x and y when the coefficient on the lagged x_t significantly differed from zero as a group. Moreover, it indicated a relationship, when y_t is the dependent variable. The coefficient on lagged y_t was significantly different from zero, when x_t is the dependent variable. (3) Independence: The causality occurred when the coefficients on x_t and y_t lagged were significantly different from zero in both equations.

If the variables are cointegrated, the vector error correction model (VECM) can be used instead of VAR. Equation (3) shows the general model for VECM.

$$\Delta y_t = \sum_{i=1}^{q} \beta_i y_{t-i} + \emptyset x_t + \gamma ECT_t + u_t \tag{3}$$

where, Δ is the first difference operator, β_i and $\emptyset$ = the parameters to be calculated, u_t = the white noise error terms, and q = the maximum lag length.

The vector error correction model (VECM) can be used for testing Granger causality between the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment. The empirical equation of VECM is presented as follow:

$$\begin{bmatrix} \Delta LCO^2_t \\ \Delta UD_t \\ \Delta LEG_t \\ \Delta LX_t \\ \Delta LM_t \\ \Delta FDI_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{j=1}^{L} \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} & \beta_{15j} & \beta_{16j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} & \beta_{25j} & \beta_{26j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} & \beta_{35j} & \beta_{36j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} & \beta_{45j} & \beta_{46j} \\ \beta_{51j} & \beta_{52j} & \beta_{53j} & \beta_{54j} & \beta_{55j} & \beta_{56j} \\ \beta_{61j} & \beta_{62j} & \beta_{63j} & \beta_{64j} & \beta_{65j} & \beta_{66j} \end{bmatrix} \begin{bmatrix} \Delta LCO^2_{t-j} \\ \Delta UD_{t-j} \\ \Delta LEG_{t-j} \\ \Delta LX_{t-j} \\ \Delta LM_{t-j} \\ \Delta FDI_{t-j} \end{bmatrix} + \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix} \tag{4}$$

where α and γ are the coefficients to be estimated and ECT_{t-1} is the lagged residual term derived from the long-run relationship. If γ is negative and significantly different from zero, it is a long-term interplay. L is the maximum lag length, Δ is the first difference operator, and ε is the error term.

Recall Equation (4). We can break it down into the following equations:

$$\Delta LCO^2_t = \alpha_1 + \sum_{j=1}^{L} \beta_{11j} \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{12j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{13j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{14j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{15j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{16j} \Delta FDI_{t-j} + \gamma_1 ECT_{t-1} + \varepsilon_{1t} \tag{5}$$

$$\Delta UD_t = \alpha_2 + \sum_{j=1}^{L} \beta_{21j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{22j} \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{23j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{24j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{25j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{26j} \Delta FDI_{t-j} + \gamma_2 ECT_{t-1} + \varepsilon_{2t} \tag{6}$$

$$\Delta LEG_t = \alpha_3 + \sum_{j=1}^{L} \beta_{31j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{32j} \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{33j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{34j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{35j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{36j} \Delta FDI_{t-j} + \gamma_3 ECT_{t-1} + \varepsilon_{3t} \tag{7}$$

$$\Delta LX_t = \alpha_4 + \sum_{j=1}^{L} \beta_{41j} \Delta LX_{t-j} + \sum_{j=1}^{L} \beta_{42j} \Delta LCO^2_{t-j} + \sum_{j=1}^{L} \beta_{43j} \Delta UD_{t-j} + \sum_{j=1}^{L} \beta_{44j} \Delta LEG_{t-j} + \sum_{j=1}^{L} \beta_{45j} \Delta LM_{t-j} + \sum_{j=1}^{L} \beta_{46j} \Delta FDI_{t-j} + \gamma_4 ECT_{t-1} + \varepsilon_{4t} \tag{8}$$

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$$\Delta \mathrm{LM}_t = \alpha_5 + \sum_{j=1}^{L} \beta_{51j}\, \Delta \mathrm{LM}_{t-j} + \sum_{j=1}^{L} \beta_{52j}\, \Delta \mathrm{LCO^2}_{t-j} + \sum_{j=1}^{L} \beta_{53j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{54j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{55j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{56j}\, \Delta \mathrm{FDI}_{t-j} + \gamma_5 \mathrm{ECT}_{t-1} + \varepsilon_{5t} \quad (9)$$

$$\Delta \mathrm{FDI}_t = \alpha_6 + \sum_{j=1}^{L} \beta_{61j}\, \Delta \mathrm{FDI}_{t-j} + \sum_{j=1}^{L} \beta_{62j}\, \Delta \mathrm{LCO^2}_{t-j} + \sum_{j=1}^{L} \beta_{63j}\, \Delta \mathrm{UD}_{t-j} + \sum_{j=1}^{L} \beta_{64j}\, \Delta \mathrm{LEG}_{t-j} + \sum_{j=1}^{L} \beta_{65j}\, \Delta \mathrm{LX}_{t-j} + \sum_{j=1}^{L} \beta_{66j}\, \Delta \mathrm{LM}_{t-j} + \gamma_6 \mathrm{ECT}_{t-1} + \varepsilon_{6t} \quad (10)$$

The long-term equilibrium is shown by the negative ECT coefficient. It indicates a correction of the variable movement towards its long-term equilibrium; hence, the coefficient should be negative. This indicates that the closer to zero the coefficient values are, the quicker the adjustment towards long-run equilibrium.

4. Results and Discussion

4.1. Empirical Results

Before examining cointegration between variables, we present an overview related to CO^2 emissions in Indonesia during the period 1971–2019. This is necessary to find out its role towards net zero emissions through the vector error correction model.

Figure 2 shows trends in CO^2 emissions that have occurred since 1971, tending to increase. It implies that significant growth in emissions has occurred since 1971, accompanied by increasing urbanization and economic growth (Figures 3 and 4). Prior to the economic crisis in 1998, an international agreement did not influence the reduction of CO^2 emissions in Indonesia. Carbon emissions constantly rose after the first United Nations Environmental Conference, which was conducted in Stockholm in 1971. Since 1998, a significant increase in economic activities, such as exports and imports (Figures 5 and 6), have led to relatively higher emissions. The Kyoto Protocol, which was signed in 1997, made the trend of carbon emissions fluctuate, as well as the Paris Agreement in 2015. It implies the influence of international agreement diplomacy on economic activities related to the reduction of CO^2 emissions. Figure 7 shows the volatility of FDI net inflows. Since the heaviest economic crisis in 1998, foreign direct investment has tended to increase. Global shocks had brought it down in 2008 and 2016, but it rose again at the end of 2019. This confirms that the interest of investors in Indonesia is still high.

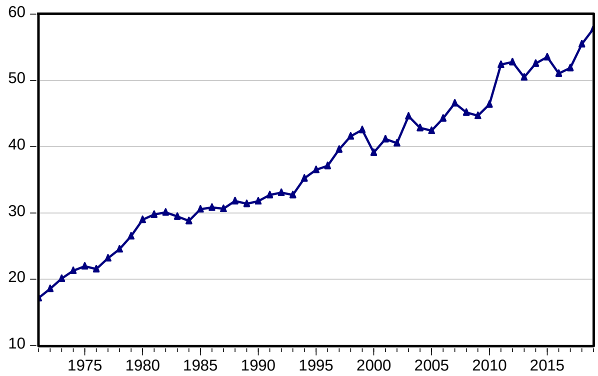

Figure 2. Time trend of CO^2 Emissions.

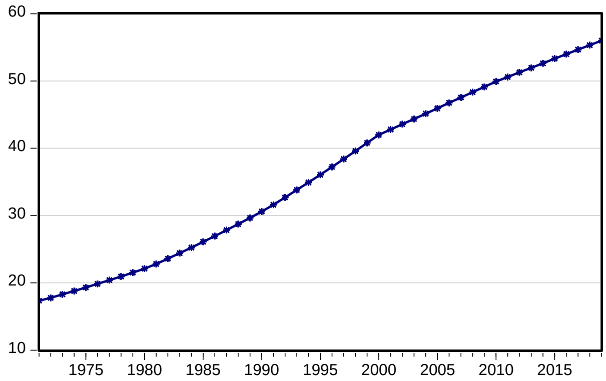

Figure 3. Time trend of Urbanization.

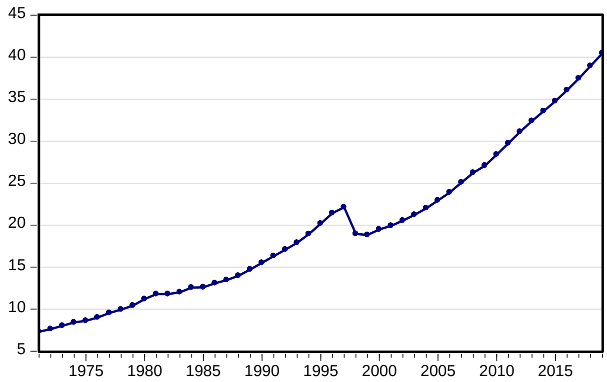

Figure 4. Time trend of Economic growth.

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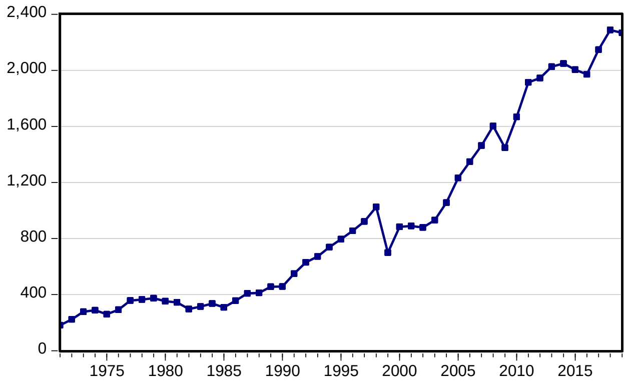

Figure 5. Time trend of Export.

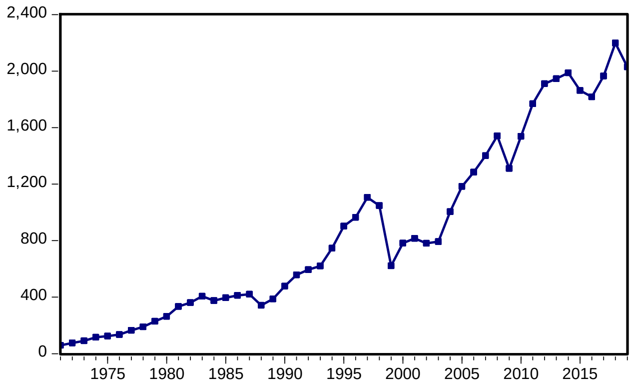

Figure 6. Time trend of Import.

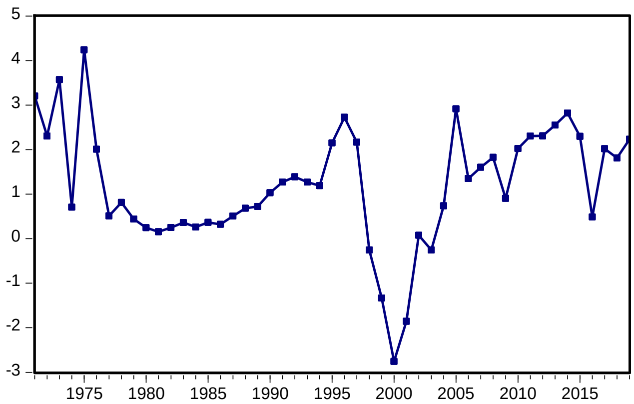

Figure 7. Time trend of Foreign Direct Investment.

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The dynamic causal relationship between CO_2 emissions, urbanization, economic growth, export, and import activities, as well as foreign direct investment, was assessed through several steps. Firstly, each variable containing the unit root was checked. Secondly, the test to determine whether there was a long-term cointegration relationship between the variables was conducted. Thirdly, the estimation of the VECM to deduce the Granger causal relationship between the variables was carried out. A summary of the results is shown in Table 4 based on the first stage, which is the unit root identification of each variable.

Table 4. Root Test of ADF-PP.

Variable	ADF		PP	
	t-Statistic	Prob.	t-Statistic	Prob.
Level				
LCO_2	−1.802599	0.3748	−2.454673	0.1329
UD	−1.697425	0.4258	0.198221	0.9697
LEG	−0.618192	0.8566	−0.606277	0.8593
LX	−0.630870	0.8536	−0.601572	0.8603
LM	−2.536889	0.1135	−2.592632	0.1016
FDI	−3.296863	0.0206	−3.348542	0.0181
First difference				
L CO_2	−5.806780	0.0000 *	−7.190028	0.0000 *
UD	−1.579417	0.4848	−1.648529	0.4502
LEG	−5.103162	0.0001 *	−5.072025	0.0001 *
LX	−8.107578	0.0000 *	−8.160933	0.0000 *
LM	−6.087550	0.0000 *	−6.087550	0.0000 *
FDI	−9.123195	0.0000 *	−9.067042	0.0000 *
Second difference				
UD	−6.02711	0.0000 *	−5.980405	0.0000 *

Remarks: * significant at the 1% level.

The first stage was the ADF unit root test, which showed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment were not stationary in the level integration analysis (Table 4). Furthermore, the first difference was conducted on all stationary variables I (1), except for the UD. This indicated that there was a difference in the level of stationarity within the UD variable, as the Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), Fisher–ADF, and Fisher–PP tests were carried out, respectively. The summary of the results is shown in Table 5. Based on the use of the Levin–Lin–Chu, Pesaran–Shin, and ADF–PP methods, the first difference root test showed that all results were stationary at I (1), due to the probability which was less than 5%. This also confirmed that the variables of CO_2 emissions, urbanization, economic growth, exports, imports, and foreign investment, were tested for cointegration.

Table 5. Group Unit Root Test.

Method	Level		First Different	
	Statistic	Prob.	Statistic	Prob.
Levin, Lin & Chu t *	−0.23198	0.4083	−7.51263	0.0000 *
Im, Pesaran and Shin W-stat	−0.50251	0.3077	−12.0491	0.0000 *
ADF-Fisher Chi-square	15.9249	0.1947	133.866	0.0000 *
PP-Fisher Chi-square	15.4927	0.2156	135.685	0.0000 *

Remarks: * significant at the 1% level. Number of observations 276.

The optimal lag length was determined based on the Akaike information criterion (AIC). According to the determination of the most optimal lag, the highest LR and low AIC, HQIC, and SBIC values were observed. The results showed the optimal lag length used was two, through the consideration of the lowest AIC value. Subsequently, a stability test was conducted to determine the usable model (VAR or VECM). The results also showed the variables to be used met the stability criteria, as the modulus values were less than one; hence, the VAR or VECM was used.

After passing the stability analysis, the cointegration test was conducted. Furthermore, the Johansen cointegration test was found to be based on the linear determinism assumption (intercept and trend). A long-term balance was observed when the trace or Max-Eigen values were more than the critical value of 5%. Therefore, the results of the Johansen cointegration test based on Trace and Max-Eigen statistics are summarized in Table 6.

Table 6. Johansen Cointegration Test.

Hypothesis	Eigenvalue	Trace-Test		Max-Eigen Test	
		Statistic	*ρ* Value	Statistic	*ρ* Value
None	0.731063	136.8953	0.0000 *	60.41077	0.0001 *
At most 1	0.504075	76.48456	0.0133 **	32.26119	0.0770
At most 2	0.361128	44.22337	0.1054	20.61038	0.3004
At most 3	0.242559	23.61299	0.2173	12.77925	0.4727
At most 4	0.159968	10.83374	0.2219	8.018521	0.3768
At most 5	0.059365	2.815217	0.0934	2.815217	0.0934

Remark: * Significant at the 1% level; ** Significant at the 5% level.

The null hypothesis of Johansen's test stated that cointegration occurred when at least one analysis was cointegrated. The null hypothesis was accepted based on the results, which showed trace and Max-Eigen test values of two and one cointegrations at the 0.05 level, respectively. This indicated that there was cointegration between variables, as CO^2 emissions, urbanization, economic growth, exports, imports, and foreign direct investment, had a long-term relationship within the period of 1971 to 2019 in Indonesia. These variables were also eligible for the VEC framework.

Based on the use of VECM, the causality source was identified from the significance test that was conducted for the coefficient of the independent variable. According to the short-term causality, the Granger causality/block exogeneity Wald tests were used to determine the nullity of the parameters associated with the independent variable in each VECM equation, through the $\chi 2$-Wald statistic. However, causality in the long term was tested by the significance of the adjustment speed. The t-statistic of the ECT coefficient that showed a long-term causal effect was also used.

Table 7 shows three out of six vectors had a negative value of ECT-1, but only Equation (5) was statistically significant at a 1% significance degree. This means only CO^2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurs from urbanization, economic growth, exports, and foreign direct investment to CO^2 emissions in the short-term. Likewise, imports into urbanization and economic growth had a one-way relationship to exports and imports (Table 7).

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Table 7. Granger Causality/Block Exogeneity Wald Tests.

Dependent Variable	Short Run						Long Run	
	ΔL(CO_2)	**ΔUD**	**ΔL(EG)**	**ΔL(X)**	**ΔL(M)**	**ΔFDI**	**Coefficient**	***t*-Test**
ΔL(CO_2)	-	18.72401 (0.0001) *	6.126103 (0.0467) **	1.802927 (0.406)	10.50891 (0.0052) *	31.76471 (0.000) *	−0.863939	−7.31613 *
ΔUD	0.885313 (0.6423)	-	0.894056 (0.6395)	1.505821 (0.471)	9.9198 (0.007) *	0.759596 (0.684)	0.62141	1.15879
ΔL(EG)	0.020633 (0.9897)	3.397833 (0.1829)	-	0.255068 (0.8803)	0.241267 (0.8864)	1.068797 (0.586)	−0.126233	−0.80081
ΔL(X)	2.835755 (0.2422)	2.549941 (0.2794)	16.40749 (0.0003) *	-	0.363593 (0.8338)	0.042006 (0.9792)	0.518394	1.31906
ΔL(M)	2.0033835 (0.3673)	1.69154 (0.4292)	30.15772 (0.0000) *	2.537506 (0.2812)	-	0.027722 (0.9862)	−0.017462	−0.03758
ΔFDI	2.94009 (0.2299)	4.537871 (0.1034)	2.024757 (0.3634)	1.783195 (0.4100)	3.849635 (0.1459)	-	11.73753	1.06675

Remark: * Significant at the 1% level; ** Significant at the 5% level; *** Significant at the 10% level.

4.2. Impulse Response

Impulse response CO_2 emissions to urbanization showed that the urban density was included in the counter-urbanization phase in the short-term. This phase is characterized by a decrease in the environmental, physical, and socio-economic carrying capacity of the population in the larger metropolitan area (Sarungu, 2001). The high level of urbanization can result in rapid population growth that leads to agglomeration and will be followed by efforts of people to fulfill their needs. Due to the speed and scale of escalation in these cities, they can induce great pressure on the environment and pose environmental degradation or threats to sustainable development (Cohen 2006). This result is in line with Agung PS et al. (2017) and Liang et al. (2019). In the long-term, CO_2 emissions will decrease along with the awareness of city dwellers about the importance of health and quality of life. This is consistent with the negative response of CO_2 emissions to urban density (Figure 8b). Therefore, urbanization can be directed to reduce CO_2 emissions by using the potential spillover of technology and high levels of education. This is consistent with Liu and Liu (2019), Hassan et al. (2020), and S. Wang et al. (2020).

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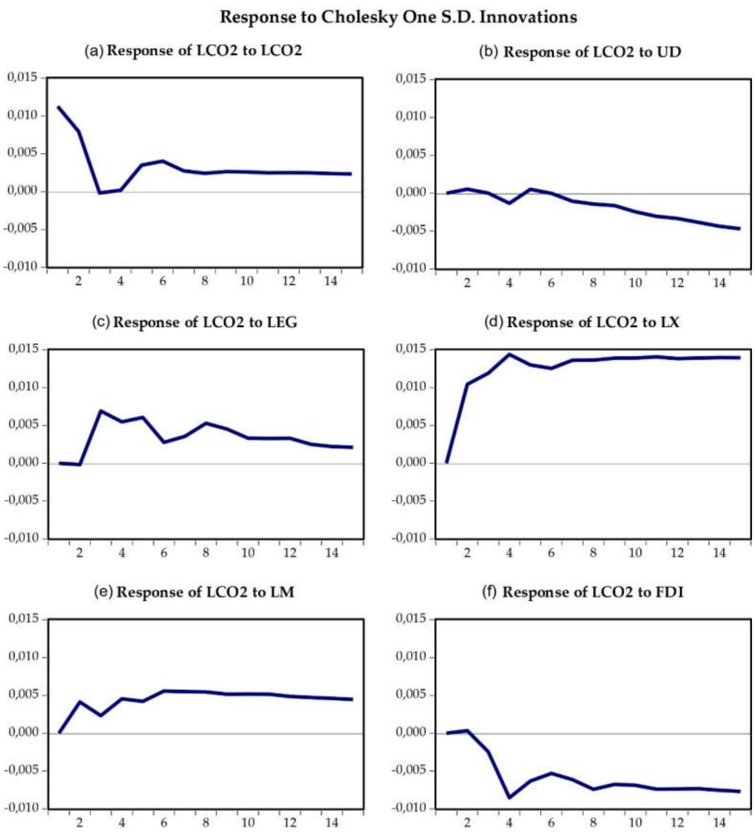

Figure 8. Impulse response functions.

Assuming FDI changes, the response of CO^2 emissions was positive in the short run, but was negative in the third year, reaching its lowest point in the fourth year, and subsequently tends to move steadily (Figure 8f). The positive response of CO^2 emissions during the shock in FDI was consistent with the VECM estimation in this study. It also showed an increase in FDI in the long run, leading to environmentally oriented investment. This is in line with Adams et al. (2020), Salehnia et al. (2020), and Chen et al. (2021). This is a great target that developing countries should build upon in order to realize the halo pollution hypothesis, along with the increasing FDI values every year. The responses of CO^2 emissions to export and import economic activities were positive. A shock to exports will increase CO^2 emissions sharply until the fourth year, and subsequently the changes tend to be stable in the long term (Figure 8d). The same pattern was shown by imports. Although the response to CO^2 emissions was smaller than the shock to exports, it was also positive to changes in imports (Figure 8e). This is a formidable challenge for net-zero carbon. Actually, the policy of goods or commodities received from the rest of the world for Indonesian consumption has led to the procurement of cordial environmental commodities which minimizes the occurrence of CO^2 emissions. The Government of Indonesia issued Statute Law Number 32 (UU No 32) in 2009 concerning Environmental Protection and Management (UU PPLH) as well as Statute Law Number 18 (UU No 18) in 2008

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concerning Waste Management (UU Waste Management). It was subsequently strengthened by the stipulation of Statute Law Number 7 (UU No 7) in 2014 concerning Trade, specifically Article 50 paragraph (1) and (2) which states that all goods can be exported or imported, except those prohibited, restricted, or otherwise stipulated by law. The newest implementation is regulated in Government Regulation No. 22 (PP No 22) in 2021 concerning the implementation of environmental protection and management. The climate change emergency at COP26 is time-bound, making net zero carbon policy mandatory for companies. Based on the results of variance decomposition (Table 8), the largest contribution to emissions comes from export activities. Therefore, failure to immediately adapt to a net zero carbon policy can lead to loss of global market share.

4.3. Variance Decomposition

Initially, the largest contribution to CO^2 emissions in the short term is the variance in the variable itself, but its contribution decreased afterward. The largest contribution was taken over by exports. Initially, it contributed only 34%, but increased continuously to become the largest at the end of the period (Table 8). Economic growth, FDI, urbanization, and imports also showed an increasing trend of contributions.

Table 8. Variance Decomposition of L CO^2.

Period	S.E.	Illustrated by Variable (%)					
		LCO^2	UD	LEG	LX	LM	FDI
1	0.01126	100	0	0	0	0	0
2	0.01778	60.0086	0.08991	0.00916	34.4567	5.39887	0.03685
3	0.02273	36.7204	0.05502	9.20014	48.4918	4.34863	1.18405
4	0.02912	22.3715	0.24277	9.14684	53.8769	5.08307	9.27894
5	0.03352	17.9672	0.20705	10.1653	55.6899	5.41679	10.5537
6	0.03693	15.9996	0.17066	8.9383	57.3913	6.7383	10.7619
7	0.04047	13.7793	0.21075	8.2149	59.0947	7.45419	11.2462
8	0.04409	11.9095	0.28457	8.34995	59.3394	7.81342	12.3031
9	0.04731	10.6518	0.36451	8.16321	60.1271	7.9719	12.7215
10	0.05029	9.69206	0.56157	7.65746	60.8523	8.11226	13.1244
11	0.05324	8.86569	0.83062	7.21289	61.2709	8.17552	13.6444
12	0.05596	8.22208	1.10796	6.87468	61.5566	8.15348	14.0852
13	0.05855	7.68971	1.4459	6.46236	61.8715	8.09846	14.4321
14	0.06108	7.21843	1.83961	6.06841	62.0817	8.00712	14.7847
15	0.06353	6.80859	2.24968	5.71815	62.1948	7.8946	15.1342

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The biggest contribution from export activities to CO^2 emissions should be the main notice related to Indonesia's commitment to achieving net-zero carbon by 2070. It should also be noted that international agreements to reduce CO^2 emissions were more or less efficient, but on the other hand, it has reduced the competitiveness and exports of several countries (C. H. Wang et al. 2019). Some countries in Asia, Europe, and America have implemented climate change mitigation programs to reduce emissions, which influences trading regulations. Requirements are set to the product; hence, it can be accepted globally by fulfilling sustainability requirements. For example, low-emission industrial product companies do not carry out deportations or execute forest conservation policies.

Foreign direct investment contributes to economic growth (Omri et al. 2014). It recognizes that investment, advanced technology, and knowledge can be transferred from industrialized countries to developing countries as an important asset to increase economic growth (Raz et al. 2012). Therefore, FDI can accelerate the speed of general purpose technologies (GPT) as the engine of growth. However, in some countries, the existence of this investment turns out to provide negative externalities to the environment, thereby proving the pollution haven hypothesis (Aliyu 2005; Aljawareen and Saddam 2017). The results showed foreign direct investment contributed significantly to CO^2 emissions. Economic agents should anticipate such factors carefully in order to remain competitive in

the global economy due to climate change. For example, the European Union makes policies regarding sanitary and phytosanitary goods to protect human and animal health, as well as environmental requirements (sustainable forest certificates and ecolabels, origin of products) for wood commodities. Other requirements, such as health and safety (free of fluorocarbon and formaldehyde emissions) and expensive costs are also not hard to manage. These should be borne by Indonesian entrepreneurs. Similarly, the Japanese government has a standard for wood products (Japan Agricultural Standard, JAS) and other export destination countries. Therefore, the right strategy is needed to synergize between economic growth air quality. Although economic activities should be carried out, it needs to be balanced in order to achieve net zero carbon.

5. Conclusions

This study aims to analyze the pattern of urbanization, economic growth, exports, imports, foreign direct investment, and CO_2 emissions. It also proved whether the halo or haven pollution hypotheses existed in Indonesia from 1971 to 2019. According to the results, CO_2 emissions had an equilibrium in the long-term. In addition, unidirectional causality occurred from urbanization, economic growth, exports, and foreign direct investment to CO_2 emissions in the short term. Likewise, imports into urbanization and economic growth indicated a one-way relationship to exports and imports. This consequently strengthened the IPAL model by Dietz and Rosa (1997), which stated that population, income, and technology are considered as the main drivers of environmental impact.

The pollution haven hypothesis exists in Indonesia, and FDI had a one-way interplay with CO_2 emissions. The government should regulate air pollution by conditioning urbanization to be environmentally friendly through building several green open spaces and public transportation that uses accommodative fuel or renewable energy. Gradually, capital should be directed to investments that promote the economy to thrive. Foreign investment is used as a pillar to support the realization of a green urban development model. This is achieved by limiting negative environmental externalities through procurement and physical investment, particularly in power generation, transportation, and manufacturing industries.

Countries that are committed to climate change prevention in the Paris Agreement should compile long-term development plans that are integrated with strategies to reduce the amount of greenhouse gas emissions. In other words, the target for reducing emissions in its implementation needs to be coherent with several existing policies, specifically Indonesia's ambition to escape from the middle-income trap. The toughest challenge for the country is the use of coal energy sources. The transfer of coal plants to renewable energy in 2040 requires the support of international cooperation, technology, economic feasibility, and international funding to assist the energy transition. Therefore, the formation of a healthy and prosperous state ecosystem can be achieved when there is collaboration from all economic agents.

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