ASSESSING THE RELATIONSHIP BETWEEN KAYA IDENTITY AND CARBON EMISSIONS: AN ECONOMETRIC AND MEDIATION ANALYSIS STUDIES IN G20 AND ASEAN MEMBER STATES

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Overview

As global greenhouse gas emissions (GHGs) keep increasing, countries worldwide have strived to curb the emissions. Implementation of a climate policy is one of the measures taken to reduce carbon emissions. Carbon pricing instruments (CPIs) are one example of a climate policy used. Currently, 64 countries have already implemented the CPIs, of which 32 of them adopted the carbon taxes, but with various rates[1]. Nevertheless, some studies show that the effectiveness of carbon tax in a country depends on four factors. The first is which targeted sectors are imposed by the carbon tax. The second is how revenues generated from the carbon tax are used in targeted areas to reduce GHG emissions, carbon tax rates, and the scope of tax exemptions[2] [3]. Despite its power to curb CO_2e, some studies show that the carbon tax implementation has some economic drawbacks[4][5]. Thus, it is critical to understand the driving factors that influence the CO_2e level. One of the well-known tools to understand these driving factors is the Kaya identity. The Kaya Identity depicts the relationship between the level of GHGs emissions with economic growth, energy use and population. Five variables form the equation: population (P), gross domestic product (GDP), fossil fuel-based energy consumption (EC), total energy consumption (TEC), and CO_2e. Therefore, analyzing the Kaya Identity and its variables could provide insights into what influences the GHGs emissions. Ultimately, a more appropriate policy to reduce carbon emissions could be formulated.

Many studies using the Kaya identity have been done to understand the relationship between GHG emissions and the underlying causes[6][7][8][9]. This paper aims to analyze the relationship between the dependent variable (CO_2e) and independent variables using mediation analysis. Building on our previous study[3], we limit the scope of this study to some G20 countries and ASEAN member states that have implemented the carbon tax system in their countries. In addition, we aimed to confirm our three proposed hypotheses: (a) the Kaya identity has a weaker presence than its decomposed variables to explain CO_2e changes; (b) GDP, Population and EC growth will increase CO_2e; and (c) TEC growth will decrease CO_2e. To the best of our knowledge, there have been no studies yet using this method for our chosen target studies.

The paper will be organized as follows. Section 1 depicts the background and purpose of this study. Section 2 reviews the hypotheses that would like to be confirmed. Section 3 describes datasets and methodologies used to identify the relationship between kaya identity and CO_2 emissions. Section 4 presents the main results based on econometrics and mediation analysis, as well as countries' energy and climate policies comparison. Last, Section 5 provides the conclusion and recommendations for future study.

Data and Methodology

We conducted a literature study and quantitative analysis to better assess the relationship between kaya identity and carbon emissions. The literature study was conducted to compare every climate policy at our study objects and identify the possible research methodology. Quantitative analysis was carried out to determine the significance of kaya identity variables and its decomposition factors on CO_2e emissions level. For this study, we conducted panel data analysis to identify the relationship between Kaya identity factors and decomposed Kaya identity factors to the CO_2e. We also estimated the suitable panel model by conducting three tests (Chow, Hausman, and Lagrange Multiplier), with a significance level of 5%. Then, we constructed parallel multiple mediator models to explore the causality between each of the Kaya identity factors as well as their respective decomposed variables and CO_2e. We also performed the widely used Monte-Carlo method to debottleneck our sample size, which was comparably small as we handled annual data. We used that method to reduce computation time, typically found in Bootstrapping analyses[10].

We created a panel dataset consisting of eight countries (Ireland, Japan, France, Mexico, Argentina, South Africa, Singapore, and Indonesia) composed annually from 1990 to 2019. The collected data were from the International Energy Agency (Total Energy Consumption and Energy Consumption) and World Bank (GDP constant 2010 (U$) and population). At last, we used all of the data to compute the Kaya Identity factors, E (energy intensity per unit of

GDP), G (GDP per capita), P (population size), M (ratio of energy consumption and total energy consumption), and F (carbon intensity of energy). Further, we also conducted a comparative analysis of our study objects' climate policies to better understand other policies related to carbon emissions reduction.

Results

We can imply that the decomposed variable of Kaya identity consisted of GDP, Population, and EC; each has a significant positive impact on CO_2e. This means that if there is an increase in GDP, Population, and EC (*ceteris paribus*), it would also increase the CO_2e. Meanwhile, TEC is statistically insignificant to the CO_2e. In the Kaya identity factors model, variables G, P, F, M and E positively correlate to the CO_2e, and excluding E, the rest of the factors significantly impact the CO_2e. Decomposed Kaya identity factor has a relatively high explanatory power, with R^2 values of 0.79, meaning that 79% of the variance of CO_2e can be explained by the variance of decomposed Kaya identity factors. Meanwhile, in Kaya identity factors, the R^2 value shows 0.31.

We applied a mediation analysis to look more deeply at the relationship between decomposed Kaya identity factors and Kaya identity factors. We found that TEC and EC strongly influence CO_2e through other independent variables. The mediation effect size varies from 47%–71%, meaning 47% to 71% of the effect of the independent variables on the dependent variable (CO_2e) is mediated by the TEC or EC. Although TEC and EC have an enormous mediation effect size, they are in a different sign. The negative coefficient that occurred in the direct path of TEC to CO_2e may imply that the case higher on TEC is estimated to be lower on CO_2e. In this regard, the literature is largely silent on this matter[11], opening potential strategic research opportunities. Contrariwise, we can observe that Kaya Identity factors have low to medium mediating effect size, showing the weaker significance in terms of mediating effects. As every decomposed variable, especially TEC and EC, has a significant effect on CO_2e (directly or indirectly), applied climate policies should reduce the intensity of these uses directly. Our comparison analysis showed that every country had promoted substantial regulation such as carbon pricing, reforestation, or promoting renewables and energy efficiency. However, more substantial commitment should be encouraged to develop CCS/CCUS facilities or abolish fossil energy subsidies.

Conclusions

This study concludes that the dynamics over CO_2e could be clearly described by the Kaya identity's decomposed variables instead of Kaya identity itself based on our econometric and mediation analysis. The TEC and EC became the variables that highly influence the CO_2e. The policymakers should see them as the main focus and enforce energy-climate policies. Implementing carbon pricing policies may become one of the proper solutions. However, combined with other energy-climate actions such as CCS/CCUS implementation, zero gas-flaring initiatives, encouraging more renewable energy use, and energy efficiency will boost the GHG mitigation efforts.

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