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ARTICLE

Higher Carbon Tax Rates More Effective in Reducing Emissions in G20 Countries?

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ABSTRACT

This study investigates the impact of carbon tax policies on carbon emission reductions in G20 countries to support the achievement of the Net Zero Emissions target by 2060. As the G20 collectively accounts for a significant share of global greenhouse gas emissions, effective policy interventions in these nations are pivotal to addressing the climate crisis. The research employs the Pearson correlation test to quantify the statistical relationship between carbon tax rates and emission levels, alongside a content analysis of sustainability reports from G20 countries to evaluate policy implementation and outcomes. The results reveal a moderate yet statistically significant negative correlation ($r = -0.30$, $p < 0.05$), indicating that higher carbon taxes are associated with lower emission levels. Content analysis further demonstrates that countries with high and consistently enforced carbon taxes, such as Japan and South Korea, achieve more substantial emissions reductions compared to nations with lower tax rates or inconsistent policy implementation. The findings emphasize that while carbon taxes serve as an effective instrument to internalize the social costs of carbon pollution, their impact is maximized when integrated with broader strategies, including investments in renewable energy, advancements in energy efficiency, and technological innovation. This research contributes to the understanding of carbon tax effectiveness and offers policy recommendations to strengthen fiscal measures as part of comprehensive climate action strategies toward achieving global sustainability targets.

Keywords: Carbon Tax; Pigouvian Tax; Carbon Emissions; Net Zero Emissions 2060; G20; Pearson Correlation Test

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1. Introduction

In global efforts to overcome the increasingly real and urgent impacts of climate change, the concept of Net Zero Emissions by 2060 has become one of the main commitments adopted by many countries, including G20 member countries. This commitment not only reflects moral and political responsibility towards sustainability but also shows awareness that without coordinated efforts the impacts of global warming will be increasingly difficult to overcome [1]. Currently, the world is facing serious challenges related to climate change caused by increasing carbon emissions which have a negative impact on the environment and the global economy [2].

Governments in various countries realize that increasing carbon emissions can trigger national economic losses and worsen climate conditions. There are various techniques for CO_2 reduction, including the use of renewable energy [3]. To overcome this risk, policies are needed that are not only effective in reducing emissions, but are also able to ensure sustainable funding for climate change mitigation [4].

One of the policies adopted by the government is the imposition of a carbon tax which is designed as an economic instrumen to internalize the externa costs of carbon pollution. This tax aims to change the behavior of society and industry towards more environmentally friendly economic activities [5].

Based on data compiled by the Emission Database for Global Atmospheric Research in 2020, Indonesia was ranked 10th as the largest carbon-emitting country in the world [6]. In response to this challenge, the Government of the Republic of Indonesia has demonstrated its commitment to achieving Net Zero Emissions by 2060, including through commitments in the Paris Agreement in 2015 and the implementation of Low Carbon Development as regulated in Presidential Regulation Number 18 of 2020 concerning Medium Term Development Plans. 2020–2024. Under the international framework of the 2015 Paris Agreement, countries committed to keeping global temperature rise below 2 °C, with additional efforts to limit it to 1.5 °C above pre-industrial levels [7]. To achieve this goal, the concept of a global carbon budget has been introduced, which refers to a limit on the amount of CO_2 emissions that can be released into the atmosphere while maintaining climate stability. According to a recent report from the Intergovernmental Panel on Climate Change (IPCC), the global carbon budget remaining to keep temperature rise below 1.5 °C is estimated to be around 500 gigatonnes of CO_2 [8]. Without significant mitigation action, this budget is projected to be exhausted within the next decade. This emphasises the importance of effective emissions reduction policies, including carbon taxes, to substantially reduce emissions and achieve long-term targets such as Net Zero Emissions 2060.

This study aims to analyse the impact of carbon tax policy on carbon emission reduction in G20 member countries during the 2016−2020 period, in order to support the achievement of the Net Zero Emissions 2060 target. The scope of this research focuses on carbon tax as the main fiscal policy instrument, highlighting the relationship between the amount of carbon tax implemented and the level of carbon emission reduction achieved [9]. The research examines the extent to which carbon tax policy contributes to carbon emission reductions in G20 countries and evaluates its effectiveness as a single instrument. In addition, it considers the need for other supporting fiscal policies, such as renewable energy subsidies or incentives for low-carbon technology development, to achieve more optimal results [10].

To achieve these objectives, this study uses the Pearson correlation test to analyse the relationship between carbon tax levels and carbon emission levels, and the content analysis method to evaluate the sustainability strategies implemented in G20 countries. The main hypothesis tested is that an increase in carbon tax has a negative and significant relationship with a decrease in carbon emissions. The research also examines whether countries with higher carbon taxes and consistent policies show more significant reductions in carbon emissions than countries with lower tax rates or limited implementation.

2. Literature Review

2.1. Carbon Tax as a Form of Pigouvian Tax

Pigouvian Tax is a tax concept imposed to overcome negative externalities arising from economic activity. Arthur Cecil Pigou first introduced this theory in his work *The Economics of Welfare* in 1920 which explained that taxes could be used as an instrument to internalize the social costs of negative impacts that are not reflected in production costs, such as pollution [11]. In this context, carbon tax is one of the real applications of Pigouvian Tax. Carbon taxes are

designed to reduce the negative impact of carbon emissions by adding social costs to the price of products or activities that cause emissions [12]. The carbon tax is calculated based on the amount of carbon dioxide produced from burning industrial fuels that produce greenhouse gas emissions. Thus, a carbon tax not only functions as a tool to reduce negative externalities but also as a mechanism that directs the economy towards a more efficient and sustainable allocation of resources [13]. The carbon tax aims to encourage the use of cleaner and environmentally friendly technology, as well as changing people's economic behavior towards a pattern of green economic behavior [14]. As a product of fiscal law, carbon tax also has a budgetary function by generating state revenue. However, the main substance of this tax does not focus on the income aspect, but rather on the regular end function, namely regulating economic behavior to be more in line with the principles of environmental sustaability [15].

In the industrial sector, Pigouvian taxes have been shown to be effective in encouraging companies to adopt cleaner and more efficient technologies, thereby contributing to the reduction of greenhouse gas emissions [11]. Conversely, in the transport sector, the implementation of these taxes can influence consumer and producer behaviour in choosing more environmentally friendly modes of transport [16]. Research shows that countries that apply carbon taxes to the transport sector experience an increase in the use of electric vehicles and public transport, which significantly reduces CO_2 emissions [17].

Furthermore, the impact of Pigouvian taxes varies depending on each country's level of industrialisation and commitment to environmental policies [9]. Some regions that implement Pigouvian taxes consistently show significant emission reductions [15]. Therefore, a more in-depth analysis of the application of Pigouvian taxes across different sectors and regions, and their impact on carbon emissions, is essential to formulate more effective policies to achieve global emission reduction goals.

2.2. Decline Carbon Emissions as Support for Net Zero Emissions 2060

Carbon emissions are the phenomenon of releasing carbon into the atmosphere that occurs as a result of natural and human activities over a certain period of time and in a certain area. Globally, carbon emissions are influenced by various factors such as economic growth, dependence on fossil energy, and increasing human population [18]. Rapid economic growth often goes hand in hand with increased industrial activity and energy consumption, much of which still relies on fossil fuels. The use of fossil energy such as petroleum, coal and natural gas is a major contributor to carbon emissions, which in turn causes an increase in greenhouse gas concentrations in the atmosphere [19].

Responding to this challenge, the government has taken concrete steps in an effort to reduce carbon emissions as part of a global commitment to curb the rate of climate change. One of the main efforts taken is to set a target of achieving Net Zero Emissions by 2060 and commit to reducing carbon emissions to reach net zero, where the emissions produced will be balanced with the amount of carbon absorbed by nature or through other carbon absorption technologies [20].

3. Research Methodology

3.1. Research Scope

This research uses quantitative data which includes carbon tax data and carbon emissions data . Secondary data sources were obtained from the World Bank. This research focuses on G20 member countries during the 2016−2020 period.

3.2. Statistical Analysis

Statistical analysis is the process of collecting, organizing, interpreting and presenting quantitative data using statistical techniques with the aim of identifying patterns, trends and relationships in the data [21]. In the context of this research, statistical analysis functions to evaluate the relationship between carbon taxes and carbon emission levels, as well as to test hypotheses regarding the impact of carbon taxes on reducing emissions [22].

3.3. Pearson Correlation Test

Pearson correlation test was used to identify the relationship between carbon taxes and carbon emission levels. The test results are expected to show a negative correlation, indicating that an increase in carbon tax is associated with a decrease in carbon emissions [23]. Interpretation of this corre-

lation coefficient will provide an understanding of the effectiveness of carbon taxes in reducing carbon emissions and evaluate the success of G20 countries' sustainability strategies to achieve the net zero emissions target by 2060 [16].

3.4. Content Analysis

Content analysis is a vital methodological approach employed in this research to evaluate and comprehend the information presented in the sustainability reports of G20 countries. This study developed a systematic coding framework designed to categorize the content of these reports effectively. The framework focuses on assessing various dimensions related to carbon emission reduction efforts and the implementation of carbon tax policies. The coding categories encompass, but are not limited to, the types of initiatives reported, the emphasis on low-carbon technologies, commitments to sustainability, and stakeholder engagement [24].

The analysis process initiates with the systematic collection of pertinent sustainability reports from each G20 country, which are then evaluated against the established coding framework. Each report is meticulously reviewed to identify and tag content that corresponds with the predefined categories. Upon completion of the coding process, the collected data is analyzed to uncover patterns, trends, and relationships associated with carbon tax policies and emission reductions. This comprehensive approach to content analysis not only offers an overview of sustainability efforts across the G20 but also facilitates a deeper understanding of how each country addresses carbon emission challenges through the policies and practices implemented [17].

4. Results

4.1. Statistical Analysis

Descriptive Statistical Analysis functions in descriptions that include the mean and median of a set of ordered data. Apart from that, this analysis includes data distribution such as maximum values, minimum values, and standard deviation values as indicators of data distribution in research [25].

Descriptive statistical analysis was conducted to examine the key characteristics of the variables under investigation, including carbon tax rates (X) and carbon emissions (Y). This analysis provides insights into the distribution and range of the data, which are critical for understanding the dynamics between these variables. **Table 1** presents a summary of the statistical properties, including the mean, median, maximum, and minimum values for both variables.

Table 1. Statistical analysis.

Descriptive Statistics	Carbon Tax (X)	Carbon Emissions (Y)
Mean	22.47883	1.997108
Median	23.59859	2.039102
Maximum	26.80889	2.821087
Minimum	12.79140	0.663988

Source: 2024 research results.

Based on **Table 1**, the average value of carbon emissions in G20 countries during the 2016−2020 period is 1.997108 CO_2 kWh^{-1} with a median value of 2.039102 CO_2 kWh^{-1}, which is slightly higher than the average indicating that the distribution of carbon emissions tends to be skewed to the left, with most countries showing emission values close to or above the median value. The maximum value is 2.821087 CO_2 kWh^{-1} and a minimum value of 0.663988 CO_2 kWh^{-1} indicates that there are significant variations in carbon emission levels between G20 countries. Countries with the highest emissions show more than four times the lowest emission values due to differences in environmental policies, levels of industrialization, or dependence on fossil fuels.

The average carbon tax of 22.47883 shows the general rate applied in G20 countries during the 2016−2020 period. This tax functions as an instrument to control carbon emissions by putting a price on CO_2 emissions. The median value of 23.59859 shows that some G20 countries set carbon taxes above the median value, while some others set it below the median value. This shows that the distribution of carbon taxes tends to be skewed towards the higher side. The maximum value of carbon tax is 26.80889 and the minimum value is 12.79140, indicating that there is quite a large variation in the implementation of carbon tax policies in G20 countries. Countries with the highest carbon taxes set rates more than double those of the lowest, reflecting differences in the commitment to emissions reduction policies and economic strategies of each country.

4.2. Pearson Correlation Test

The Pearson correlation test was employed to evaluate the strength and direction of the linear relationship between the carbon tax variable (X) and the carbon emissions variable (Y). This statistical test is particularly useful for quantifying the extent to which an increase in carbon tax rates is associated with changes in emission levels. The hypothesis for the Pearson correlation test is formulated as follows [26]:

H_0: There is no significant correlation between carbon tax rates and carbon emissions.
H_a: There is a significant correlation between carbon tax rates and carbon emissions.

The decision rule is based on the p-value:

If $p < 0.05p$, H_0 is rejected, and H_a is accepted.
If $p > 0.05p$, H_0 is accepted, and H_a is rejected.

The results of the correlation analysis are presented in **Table 2**, which displays the correlation coefficient (r) and the significance level (p-value) for the relationship between the variables. As indicated in the table, the findings reveal a statistically significant negative correlation, suggesting that higher carbon tax rates are associated with lower emission levels.

Table 2. Pearson correlation test.

Correlation Probability	X	Y
X	1,000000	
Y	−0.304561 0.0079	1.000000

Source: 2024 research results.

Based on the Pearson correlation test results shown in **Table 2**, there is a negative relationship between the carbon tax variable (X) and carbon emission reduction (Y) with a correlation coefficient of −0.304561. This value indicates a moderate and statistically significant relationship between the two variables. In other words, when carbon tax increases, there tends to be a decrease in carbon emissions. The probability value (P-Value) obtained is $0.0079 < 0.05$, indicating that at the 5% significance level ($\alpha = 0.05$), the null hypothesis (H0) states that there is a relationship between carbon tax and carbon emission reduction.

This moderate correlation indicates that carbon tax policy has a statistically significant impact and has implications especially in complex systems such as carbon emissions and environmental policy. The correlation of −0.304561 suggests that carbon tax contributes to emission reductions, but other factors, such as technological advancements, industrial practices, and national environmental policies may also play a role in influencing emission levels. Therefore, while this correlation is moderate, its statistical significance suggests that carbon tax policy is an important part of a broader strategy to reduce emissions.

5. Discussion

The Effect of Carbon Taxes on Reducing Carbon Emissions in G20 Countries as a Strategy to Achieve Net Zero Emissions 2060

Based on the results of research conducted on G20 countries during the 2016−2020 period, it was found that there is a negative and significant relationship between carbon taxes and carbon emissions. This research confirms the theoretical view that carbon taxes are an effective instrument in reducing carbon emissions, showing that countries that impose higher carbon taxes succeed in reducing their carbon emission levels more effectively compared to countries that impose lower carbon taxes [27]. This policy plays an important role in mitigating climate change. In the context of the G20, where countries are the main contributors to global emissions, the implementation of a carbon tax has a substantial impact in reducing the carbon footprint [28].

The implementation of higher carbon taxes will not only trigger behavioral changes at the producer and consumer level, but also accelerate innovation in clean energy technologies. Manufacturers in countries with high carbon taxes are adopting more technologies that reduce carbon emissions, sch as capture and storag (CCS) technology, renewable energy, and increased energy efficiency. On the other hand, consumers will be encouraged to choose products and services that are more environmentally friendly, such as electric vehicles or solar energy for households. This innovation will ultimately accelerate the transition from a fossil fuel-based economy to a low-carbon economy, in line with the global commitment to achieve Net Zero Emissions by 2060 [29]. This is in accordance with environmental economic theory which states that the internalization of the social costs of pollution through taxes can significantly influence eco-

nomic decisions, leading to better environmental outcomes and thereby contributing to achieving emissions reduction targets [30]. However, it is important to consider the influence of external factors, such as the economic downturn due to COVID-19, which may have played a role in the decline of emissions during the study period from 2016−2020. The COVID-19 pandemic led to a significant decline in industrial and transportation activity worldwide, which contributed to the temporary decline in carbon emissions. In addition, structural shifts in the energy sector, such as the transition from fossil fuels to renewable energy, also likely contributed to the decline in emissions, independent of the impact of the carbon tax.

As illustrated in **Figure 1**, the data shows a clear trend that supports the relationship between carbon tax implementation and emissions reduction.

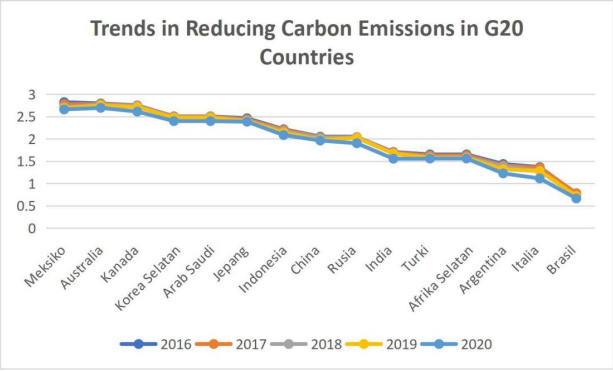

Figure 1. Trend in reducing carbon emissions in G20 countries for the 2016−2020 period.

Mexico is a country in Latin America that implemented a carbon tax in 2014, with relatively low rates. This tax focuses on the energy and transportation sectors. The impact of the carbon tax in Mexico is still limited, but there has been a moderate reduction in emissions due to increased energy efficiency and the adoption of green technologies in the industrial sector. Mexico has set a target to achieve Net Zero Emissions by 2060 with a strategy that includes increased use of renewable energy, energy efficiency, and environmental policy reform [31].

Australia has experienced a moderate reduction in emissions due to increased use of renewable energy, especially solar and wind. However, dependence on coal exports remains a major challenge. Australia has committed to achieving Net Zero Emissions by 2060, with a focus on developing low-carbon technologies, although consistent and comprehensive policies are still needed [32].

Canada implements a national carbon tax with gradually increasing rates. This policy is accompanied by a mechanism to return the majority of tax revenues to the community. Since the implementation of the carbon tax, emissions have been seen to decrease, especially in the transportation and eergy sectors. Carbon taxe encourage the transition to electric vehicles and increased energy efficiency. Canada has set a target to achieve Net Zero Emissions by 2060, with measures such as major investments in renewable energy, carbon capture and storage (CCS), and energy policy reform [33].

South Korea had an emissions trading system (ETS) similar to a carbon tax in 2015, as part of efforts to reduce carbon emissions. This policy covers various sectors, including energy, industry and transportation. Since the implementation of the ETS, South Korea has seen significant reductions in emissions in the sectors covered by the scheme, mainly through increased energy efficiency and the adoption of low-carbon technologies. South Korea is committed to achieving Net Zero Emissions by 2060, with a strategy that includes developing renewable energy, electrifying the transportation sector, and reducing the use of fossil fuels.

Saudi Arabia is starting to introduce environmental policies, including a carbon tax, but these policies are still in their early stages and rates are low. The impact of the carbon tax policy is still not significant, but Saudi Arabia is trying to reduce emissions through economic diversification and investment in renewable energy. Saudi Arabia has set a target to achieve Net Zero Emissions by 2060, with a strategy that includes developing renewable energy, reducing domestic oil use, and increasing energy efficiency [34].

Japan implemented a carbon tax progressively, starting in 2012. This tax applies to sectors with high emissions such as industry and transportation. The carbon tax has driven emissions reductions in Japan, primarily through increased energy efficiency and the adoption of low- carbon technologies such as CCS and electric vehicles. Japan has set a target to achieve Net Zero Emissions by 2060. This strategy includes large investments in renewable energy, increased energy efficiency, and the development of new technologies such as hydrogen and CCS [35].

Indonesia is starting to introduce a carbon tax policy with a focus on the energy and industrial sectors. This policy is still in the early stages of implementation and requires

stronger support. Emission reduction in Indonesia is still limited, with heavy dependence on coal as the main energy source. However, there are efforts to increase the use of renewable energy and energy efficiency. Indonesia is committed to achieving Net Zero Emissions by 2060. This strategy includes developing renewable energy, reducing deforestation, and increasing energy efficiency [36].

China has developed and implemented an emissions trading system (ETS), starting with a pilot scheme in several cities and provinces in 2013 before launching a national ETS system in 2021. This ETS system covers large energy and industrial sectors, aiming to monitor and reduce carbon emissions through allocation quotas and emissions trading. China has seen a significant reduction in carbon emissions thanks to strict pollution control policies and large investments in renewable energy. The country is a global leader in renewable energy capacity, especially in solar and wind power. China is committed to achieving Net Zero Emissions by 2060, with a strategy that includes increasing the use of renewable energy, electrifying the transport sector, and developing low-carbon technologies such as hydrogen and carbon capture. In addition China has a strategy to rduce carbon intensity per unit of GDP and accelerate the transition from coal to clean energy [37].

Russia is starting to implement a carbon tax in several sectors but rates are still very low and implementation is limited. Although Russia remains one of the largest emitters, there are several efforts to improve energy efficiency and reduce emissions in certain sectors. Russia has set a target to achieve Net Zero Emissions by 2060, with a focus on modernizing the energy sector, reducing dependence on fossil fuels, and improving green technologies.

India has started implementing a carbon tax policy in the form of a CESS (levy) on coal since 2010, which aims to reduce dependence on fossil fuels. This tax was strengthened in the 2016−2020 period. Emission reduction in India remains limited due to high levels of economic growth and dependence on coal. However, there has been a significant increase in the use of renewable energy such as solar and wind. India is focusing on increasing renewable energy capacity and energy efficiency as part of its long-term strategy to reduce emissions [38].

Türkiye has developed various policies to reduce emissions, including energy efficiency standards and incentives for renewable energy. Emission reductions in Türkiye are still limited due to high levels of economic growth and dependence on coal. However, there is an increase in the adoption of renewable energy, especially in the energy sector [39].

South Africa is starting to implement a carbon tax at a relatively low and gradual rate. This tax is applied in various sectors, including electricity, industry and transportation. The impact of the carbon tax is starting to be seen, with moderate emissions reductions in the energy sector, mainly due to increased investment in renewable energy, although dependence on coal remains high. South Africa has set a target to achieve Net Zero Emissions by 2060, with a focus on the transition from coal to renewable energy, improving energy efficiency, and investing in clean technologies [40].

Argentina began implementing a carbon tax with rates that were initially low but gradually increased. This tax focuses on the energy sector, especially fossil fuels. The impact of the carbon tax in Argentina remains limited, but there is increasing awareness and investment in renewable energy, such as wind and solar power. Argentina has stated a strategy to achieve Net Zero Emissions by 2060, with a focus on developing renewable energy, increasing energy efficiency, and reducing emissions from the transportation sector [41].

Italy has implemented a carbon tax since early 2010 as part of the European Union's efforts to reduce carbon emissions. This tax is applied in the transportation and energy sectors. Italy has succeeded in reducing carbon emissions significantly, mainly through increasing the use of renewable energy and energy efficiency in the transport and building sectors. Italy is committed to achieving Net Zero Emissions by 2060, with a focus on the energy transition, increasing energy efciency and developing gren technologies [42].

Brazil has adopted various policies to reduce emissions, including incentives for renewable energy and efforts to reduce deforestation. Emission reductions in Brazil remain limited, mainly due to continued deforestation in the Amazon. However, there is progress in the use of bioenergy and hydropower as renewable energy sources. Brazil is committed to achieving Net Zero Emissions by 2060, with a strategy that includes reducing deforestation, increasing renewable energy, and increasing energy efficiency in the transportation and industrial sectors [43].

6. Conclusions

This research shows that higher carbon taxes generally contribute to lower carbon emissions in G20 countries over the 2016−2020 period. However, this finding needs to be understood contextually, as the impact is not uniform across G20 countries. While carbon taxes have proven effective in developed countries with a strong commitment to environmental policies, such as Japan and Germany, similar results may not hold in countries with different economic structures.

Countries that are highly dependent on fossil fuels or facing economic challenges, such as Indonesia and Saudi Arabia, may not experience significant emission reductions even if carbon tax rates are increased. This is due to structural factors, including dependence on carbon-based energy, varying levels of industrialization and inconsistent environmental policies. In addition, developing countries may face greater difficulties in integrating carbon tax policies with effective energy transition strategies, resulting in more variable outcomes compared to developed countries. Therefore, this conclusion emphasizes the importance of considering the economic diversity and policy challenges in G20 countries. Carbon tax policies need to be tailored to each country's economic and environmental context to achieve optimal results.

7. Suggestions

A carbon tax that is consistently implemented and even gradually increased could accelerate the transition to a low-carbon economy. This is in line with long-term goals such as the Net Zero Emission target by 2060 launched by many countries. However, to achieve sustainability in reducing emissions, carbon taxes need to be combined with other complementary policies, such as investment in renewable energy, support for green innovation, and regulations that encourage energy efficiency in various economic sectors. Therefore, a more holistic and collaborative strategy is needed, involving all stakeholders to achieve long-term success in reducing emissions and mitigating the impacts of climate change globally.

Author Contributions

Conceptualization, methodology, project administration, resources, supervision, validation, visualization, writing—original draft, writing—review & editing: H.W.; conceptualization, investigation, project administration, resources, software, visualization, writing—original draft, writing—review & editing: S.M.L.

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Data will be available on request from the author.

Conflicts of Interest

All authors have read and agreed to the published version of the manuscript.

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