frontiers | Frontiers in Environmental Science

TYPE Data Report
PUBLISHED 28 February 2023
DOI 10.3389/fenvs.2023.1065301

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

RECEIVED 09 December 2022
ACCEPTED 08 February 2023
PUBLISHED 28 February 2023

CITATION
Sasmoko, Imran M, Khan S, Khan HuR, Jambari H, Musah MB and Zaman K (2023), War psychology: The global carbon emissions impact of the Ukraine-Russia conflict.
Front. Environ. Sci. 11:1065301.
doi: 10.3389/fenvs.2023.1065301

War psychology: The global carbon emissions impact of the Ukraine-Russia conflict

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KEYWORDS

Ukraine arms imports, Ukraine armed forces personnel, Russian military expenditures, war, global carbon emissions

1 Introduction

The international community has created several vital frameworks to combat climate change and advance sustainable development, including the Paris Agreement and the Sustainable Development Goals (SDGs) (Fuso Nerini et al., 2019). To keep the global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C, the Paris Agreement was adopted in 2015 as a legally binding agreement under the United Nations Framework Convention on Climate Change (UNFCCC) (Rogelj et al., 2016). In contrast, the UN established the SDGs in 2015 as a worldwide call to action to eradicate poverty, safeguard the planet, and guarantee that all people live in peace and prosperity by 2030 (Caetano et al., 2020).

Considering the low-carbon advantages of repairing the ecological damage caused by the war in Ukraine is critical in light of these international accords. The research may help achieve the aims of the Paris Agreement by lowering global carbon emissions by decreasing the large volumes of greenhouse gases emitted as a consequence of the war. The research may also help advance the SDGs by raising awareness of the importance of sustainable development and tackling the environmental damage that has resulted from the conflict. The study's examination of the costs and benefits of various mitigation and adaptation options may also give significant insights to policymakers and stakeholders on promoting low-carbon development through the Paris Agreement and SDGs. Strategies like these may help reduce greenhouse gas emissions and push sustainable development forward. They can include investing in renewable energy, encouraging energy efficiency, and introducing carbon price systems. In short, the study's emphasis on the environmental effect of the war in Ukraine and analysis of possible costs and benefits of alternative mitigation and adaptation options might contribute to the low carbon benefits in light of the Paris Agreement and SDGs. Greenhouse gas emission reductions and the promotion of sustainable development are two key factors in responding to the threats posed by climate change, and this may assist.

Wars have had far-reaching effects on the natural world, the economy and monetary system, international commerce and progress, and people's lives everywhere. In the form of increased costs, unsustainable economic growth and development, and enduring

fluctuations in the financial and macroeconomic cycle, trading partners and adjacent countries also feel uncertain due to the geographic and conflict risks that extend across the region (Khudaykulova et al., 2022). According to Orhan (Orhan, 2022), Russia's 2014 involvement in Ukraine was a response to the country's escalating crisis brought on by its decision to strengthen ties with the European Union and the North Atlantic Treaty Organization (NATO), both of which are in the interest of Russia's inner circle. As part of their invasion, they occupied eastern Ukraine and annexed Crimea. Russia initiated a military campaign in the area to rid Ukraine of troops and Nazism after Crimea proclaimed independence invoking the right of "self-determination" in an aggressive manner. Because of its strategic location and historical significance to Russia, Ukraine is of utmost importance to the Russian Federation. International attention was drawn to the situation when the Ukrainian government announced that it would not be signing the Association Agreement with the European Union (EU) as planned in November 2013. This situation escalated when Russia annexed Crimea and became a global issue that descended into civil conflict. Earlier research focused on environmental issues without evaluating the consequences of war, which are essential to analyze for reducing the emissions caused by conflict (Awan et al., 2018; Awan and Sroufe, 2020; Khan et al., 2021a; Awan and Sroufe, 2022; Begum et al., 2022).

Pearce (Pearce, 2022) claims that conflicts between industrialized nations devastate the planet's natural and built environments, destroying millions of acres of forestland, countless species of animals, and countless miles of highways and power lines. Rawtani (Rawtani et al., 2022) claims that the current conflict between Russia and Ukraine is the most significant confrontation in Europe. It has had far-reaching effects on geopolitics, the economy, infrastructure, and the environment on a local and international scale. War destroys material goods and social and natural systems, which may negatively affect human and environmental health. There is a severe water shortage, and the sanitation system and air quality are negatively impacted by the frequent movement of troops and the incessant bombardment. Large-scale deforestation and wildfires, fueled partly by nuclear radiation and military activities, are significant contributors to global warming and other environmental crises. Beginning in 2020, the COVID-19 epidemic had a significant influence on the worldwide agenda, as Pereira et al. (Pereira et al., 2022) reported. The severe conflict between Ukraine and Russia exacerbated a global tsunami that began with crippling increasing inflation and global insecurity in various aspects, including food, energy, and financial order. It imposed an additional and strong disturbance on the global economy and reduced the ability of many countries to achieve the SDGs by 2030.

The large bulk of earlier studies discussed the need to achieve sustainable development through variety of policy instruments (Hassan et al., 2020; Fatima et al., 2021; Chang et al., 2022; Chaudhry et al., 2022; Numan et al., 2022; Suki et al., 2022; Sun et al., 2022), while a brief literature review compiles material on the Ukraine–Russia conflict and other pieces of evidence on global climate and environmental disruption, which are projected to grow in the future (Avis, 2022).

The study has the following three research questions.

I. Does the arms import between the economies create greater tension, endangering economic and environmental resources?
II. How much is the degradation of the world's ecosystem attributable to the expansion of the military?
III. Are military expenditures on war weapons and instruments increasing global carbon emissions? And
IV. Does an increase in the duration of war/conflicts collateral damage both nations, jeopardizing the green developmental agenda?

The study's overarching goal is to learn how Russia and Ukraine's war might impact the world's ecosystems *via* armament exports, military recruitment, and military spending. The following research questions were explored in the study.

I. To determine the effects of Ukraine arms imports and increasing armed forces personnel on the global environment to support the ammunition-emissions hypothesis.
II. To analyze the impact of Russian military expenditures on carbon emissions to verify the defense burden hypothesis, and
III. To investigate the impact of war/conflicts between two countries on the environmental sustainability agenda.

The novelty of this study lies in its focus on the specific research problem of costing out the environmental damage caused by the conflict in Ukraine. The war's environmental impacts are assessed in the research, focusing on the enormous quantities of greenhouse gases generated as a consequence of the warfare. The distinctive contribution of the research is the combination of cross-panel data on the impact of Ukrainian and Russian arms and ammunition on global carbon emissions. Previous studies have mainly concentrated on the human and economic consequences of the war rather than its influence on the environment, making this a crucial and under-explored field of study (Trypolska and Rosner, 2022; Zhou et al., 2023). The research intends to contribute to the field on several fronts, as described above. In order to give a thorough evaluation of the conflict's effects on the environment, the research combines several analytical approaches, including ecological and economic models (ul Deen and Farooq, 2023; Prisecaru, 2022). This research is also noteworthy since it is one of the first to examine the effects of the Ukrainian war on the global ecosystem. There is a growing amount of literature on the environmental consequences of armed conflicts, but the situation in Ukraine has received less attention. With the lack of a comprehensive investigation of the environmental effects of the crisis in Ukraine, this study seeks to address that void. Cost-benefit analyses of various mitigation and adaptation techniques are also included in the research. This enables the research to give actionable suggestions for repairing the conflict's environmental harm and contributing to policy choices. The overarching goal of the research is to thoroughly examine the environmental effect of the war in Ukraine by drawing on various academic disciplines and offering concrete solutions to the issue.

The following studies (Işık, 2013; Isik et al., 2021; Işık et al., 2021; Işık et al., 2022; Ongan et al., 2022) investigated the Environmental Kuznets Curve (EKC) hypothesis and its relationship with government spending, economic growth, and environmental degradation. They have also studied the convergence of ecological

footprint in several nations, including the United States, Turkey, and the North American Free Trade Agreement countries, and determined the link between the EKC hypothesis and the ARMEY curve model (NAFTA). While these studies have made significant contributions to the field of environmental economics, they have yet to specifically focus on the environmental impact of the conflict in Ukraine. On the other hand, this study is groundbreaking in its integration of cross-panel data on the impact of Ukraine-Russian arms and ammunition on global carbon emissions and its narrow emphasis on a particular research subject of estimating the costs to the environment from the crisis in Ukraine. In addition, this research endeavours to give a multidisciplinary analysis of the environmental effect of the Ukraine crisis and provide concrete solutions to the issue. The research also includes evaluating the costs and benefits of various mitigation and adaptation measures that may aid in fostering sustainable development and cutting down on greenhouse gas emissions. This research is the first of its kind to examine the environmental effect of the crisis in Ukraine and its contribution to the low carbon benefits in light of the Paris Agreement and SDGs. At the same time, the referenced works have investigated many elements of environmental economics.

2 Data and methodology

The study used the cross-panel panel data from 1995 to 2020 from the World Development Indicators (WDI, 2022). Previous research on cross-panel data has shown that one country's socioeconomic and environmental policies can impact another country due to negative externalities (SasmokoSamuel et al., 2022). This is particularly relevant in the era of globalization, where no country operates in isolation (Zaman, 2023). In this study, data on worldwide carbon emissions (WCO2) were pooled from aggregate Europe and the rest of the globe to serve as the dependent variable. The independent variables in this study were sourced from the economies of Ukraine and Russia. This approach allows for a more comprehensive understanding of the relationship between carbon emissions and war factors, as it considers the influence of multiple countries. By pooling data from different countries and using a cross-panel analysis, this study offers a unique perspective on the relationship between military factors and carbon emissions. The following are the study's independent variables: The independent variables of the study are as follows.

I. The SIPRI trend indicator data for Ukraine's weapons imports (denoted by UARM) are plotted against Europe's emissions, while R&D investment is plotted against the world's carbon emissions.
II. Ukraine military expenditure was plotted for worldwide carbon emissions, while the number of Ukrainian military personnel (total) was plotted against European emissions (denoted by UAFP).
III. Russian military spending as a percentage of GDP (denoted by RMEX) is plotted against European emissions, while Russian arms imports are plotted against global carbon emissions, and
IV. A war dummy (denoted by DWAR) with a value of one is plotted for 2014–2020, when tensions between the two countries peaked, while a value of 0 is plotted for 1995–2013.

3 Theoretical framework

The study followed the earlier studies and mainly discussed three main areas of investigation.

I. First, military spending adversely affected economic growth to substantiate the defense burden hypothesis (Zaman et al., 2012; Ul Ain et al., 2019).
II. Secondly, the aggregated demand theory (supply-side spillover impact) is supported by the fact that military expenditure boosts growth-specific elements like foreign tourism and decreases international terrorism (Nassani et al., 2017; Choudhary et al., 2020). In addition, increased military expenditure enhances corporate regulatory affairs, making investors feel more at ease with their decisions to put money into a country (Zaman, 2019), and
III. Third, there is evidence for the ammunition-emissions hypothesis in the form of lead-containing gas emissions, which also include carbon emissions, from the supply of guns and ammunition.

In order to provide evidence for the aforementioned premise, this research analyzed the literature to determine the effect the war or conflict between Ukraine and Russia has had on world carbon emissions.

3.1 Methodology

The fixed effect statistical method stated in Eq 1 was used in this research since it accounts for variability in the data and provides its unique intercept. To determine whether a common constant or fixed effect is preferable for regression analysis, we first conducted a redundant fixed effects test (Chow test).

$$\begin{aligned} \mathrm{In}\,(\mathrm{WCO2})_{i,j,t} = {} & \alpha + \beta_1 \mathrm{In}\,(\mathrm{UARM})_{k,l,t} + \beta_2\,(\mathrm{UAFP})_{m,n,t} \\ & + \beta_3\,(\mathrm{RMEX})_{o,p,t} + \beta_4\,(\mathrm{DWAR})_{i,j,t} \\ & + \varepsilon_{i,j,k,l,m,m,o,p,t} \ldots\ldots\ldots . \end{aligned} \tag{1}$$

Where; WCO2 shows world's carbon emissions, UARM shows Ukraine arms imports, UAFP shows Ukraine armed forces personnel, RMEX shows Russian military expenditures, DWAR shows war dummy, 'i' shows European data, 'j' shows World aggregated data, 'k' shows Ukraine arms data, 'l' shows Ukraine R&D data, 'm' shows Ukraine armed force data, 'n' shows Ukraine military spending data, 'o' shows Russian military spending data, 'p' shows Russian arms imports data, 't' shows time period, and ε shows error term.

4 Results and discussion

Before moving on to the estimate of the fixed effect model, it is necessary first to conduct the redundant fixed effects test, also known as the Chow test, to pick either the common or the fixed effect model. Since the Chow test result is statistically significant at the 1% level, the fixed effect model is preferable to the common constant model. Table 1 displays the results of the fixed effect model

TABLE 1 Fixed effect model estimates.

Variables	FE-1	FE-2	FE-3	FE-4	FE-5
Constant	1.004* (0.000)	0.625 (0.061)	1.013* (0.000)	0.926* (0.000)	1.649* (0.000)
UARM	1.510* (0.000)	--------	1.545* (0.000)	1.494* (0.000)	---------
UAFP	0.013** (0.094)	0.154* (0.000)	--------	0.015* (0.051)	0.156* (0.001)
RMEX	−0.033 (0.123)	0.379* (0.002)	−0.040 (0.066)	----------	----------
DWAR	0.006 (0.868)	−0.0006 (0.977)	0.0001 (0.958)	−0.003 (0.272)	0.051* (0.004)
R^2	0.9993	0.972	0.99927	0.99928	0.966
Adjusted R^2	0.9992	0.969	0.99921	0.99922	0.964
F –Test	13531.66*	409.658*	16250.15*	16402.11*	458.221*
Chow Test	14.957*	752.215*	11.651*	35.745*	1180.250*

Note: * and ** indicates 1% and 5% significance level. FE, shows fixed effect model estimates.

for convenience. To confirm the ammunition-emissions hypothesis and the emissions-defense burden hypothesis, we find that increases in Ukraine's weapons imports, Ukraine's armed force's manpower, and Russian military expenditures raise global carbon emissions. The rising tension between the two nations was proved to negatively influence global economic and environmental resources by the positive correlation between the war dummy and worldwide carbon emissions. Therefore, moving toward long-term solutions and negotiations to end the war or conflict is necessary. These results are in line with those found in the work of Khan et al. (Khan et al., 2021b), Smith and Lengefeld (Smith and Lengefeld, 2020), and Ahmed et al. (Ahmed S. et al., 2020). Reducing the production of guns and strengthening the foundation of international law regarding the manufacture and supply of arms are two key recommendations based on the results, both of which are necessary to preserve global prosperity and protect the environment.

Increasing the usage of renewable energy in military vehicles may help reduce emissions and hence the environmental impact of the military. Further, testing nuclear weapons and atomic-nuclear bombs, which undermine environmental sustainability, must be reduced, and biodiesel renewable energy is required to do so. The military uses vast amounts of petroleum in its aircraft, ships, and tanks (Jorgenson and Clark, 2009; Hooks and Smith, 2013; Bildirici, 2017; Isiksal, 2021). In order to sustain economic development without causing irreparable damage to the natural world, it is essential to reduce industrial and military expenditures and to

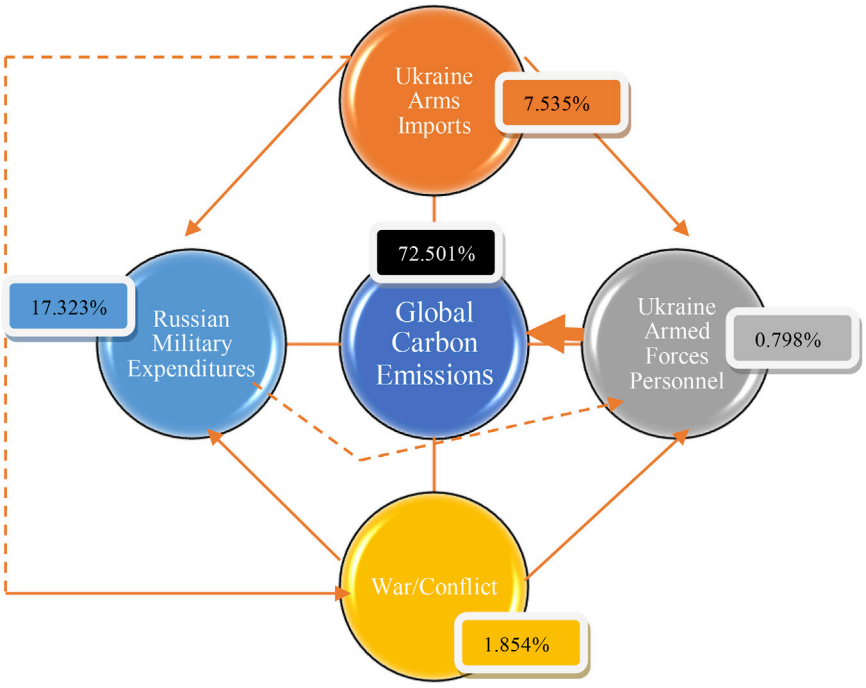

FIGURE 1
Granger causality and VDA estimates.

urgently push the adoption of eco-friendly manufacturing processes for military and industrial activity (Ahmed Z. et al., 2020; Gokmenoglu et al., 2021; Kwakwa, 2022). Maintaining a global perspective is essential for environmental sustainability, requiring a military budget reduction (Wang et al., 2021; Erdogan et al., 2022). Towards a more sustainable global environment, international organizations provide peace and stability amongst once-at-odds nations and implement innovative legal frameworks and environmental changes. In addition, the international disputes between economies and the construction of long-term peace should be prioritized (Anser et al., 2021; Cai and Wu, 2021).

Using Granger causality and VDA estimations (as shown in Figure 1), we discovered that individuals in the Ukraine armed forces Granger cause global carbon emissions, lending credence to the ammunition—emissions hypothesis. In addition, Russian military expenditures and war/conflicts between the nations directly result from Ukraine's weaponry purchases. When there is conflict or war, Russia and Ukraine raise their military budgets and the number of people serving in the military.

Russian military expenditure is expected to have the greatest impact on world carbon emissions, with a variance shock of 17.323%, followed by weapons imports into Ukraine (7.535%), war and conflict (1.841%), and armed forces personnel (0.798%).

5 Conclusion

The military-growth nexus has been given the greatest attention in the security and conflict discourse. In contrast, the eco-efficiency agenda, which is affected by ongoing high weapon deployments, has gotten less attention. Manufacturing lead-containing ordnance releases hazardous gas combinations and chemicals, including carbon dioxide emissions, which hamper international healthcare efforts. Ukraine-Russian ongoing war threatens global environment by releasing ammunition emissions extensively into the environment leading to the healthcare hazards. The research analyzed the worldwide environmental effects of three factors: Ukrainian weapons imports, Ukrainian military manpower, and Russian military spending. The research used panel data and a fixed effect model from 1995 to 2020. The findings of this analysis provide credence to the ammunition-emissions hypothesis by showing a positive correlation between the aforementioned military parameters and global carbon emissions. According to the Granger causality estimates, there is a link between the number of Ukrainian military personnel and world carbon emissions, whereas Russian military expenditure is a Granger cause of Ukrainian military personnel. Ukraine arms imports Granger cause Russian military spending and increasing war/conflict. According to the projections, Ukraine weapons purchases would provide the greatest variation shock to carbon emissions, followed by Russian military expenditures.

Less known are the far-reaching repercussions on the environment brought on by Russia's protracted invasion of Ukraine, which has caused tremendous suffering, death, and damage. The growing military budgets of both Russia and Ukraine have negative impacts on the environment. During the Ukraine war, several measures may be implemented to lessen the military's impact on the environment.

1) Switching to fuel-efficient military vehicles might help reduce the greenhouse emissions airstrikes produce over time.
2) Using wind turbines may aid in minimizing the dependency on fuels derived from petroleum and the quantity of carbon created.
3) During military operations, implementing energy conservation measures such as turning off lights and gadgets when they are not in use and utilizing more energy efficiency will assist in minimizing the amount of energy used and the emissions produced.
4) Lessening the need for in-flight personnel by increasing the frequency with which virtual meetings and other wireless traffic are used might save money and fuel, and
5) Fostering environmental operational practices such as deploying intelligent transport modes and optimizing routes may assist in lowering the greenhouse gases produced by missile launches.

It is important to note that the military is not the only partaker responsible for decreasing battlefield emissions; legislatures and other parties to the war also have a role to play. There has to be cooperation between the warring sides to discover solutions that will lessen the environmental and health damages being done by the fighting. Direct emissions from weapons, aircraft, armour, and vehicles that fuel the stalemate are hard to calculate while fighting and hence are not included in the Paris goal of limiting warming to 1.5°C. An all-out switch to renewables is needed if we succeed in keeping global warming, which means less money from carbon fuel exports to spend on extensive war equipment, promoting peace. After Russia invaded Ukraine, a previously planned energy shift found itself at a critical juncture. The takeaway for policymakers is that transitioning away from fossil fuels is essential if we want to prevent an extreme climate scenario. Ukraine will be contaminated for decades by the war's pollution. There are hidden consequences to Russia's invasion due to chemical spills and widespread fires. Managing the safety of weaponry and transitioning to lead-free ammo would help a government get closer to its sustainability goals.

Economic policy uncertainty significantly influences tourist demand, which is relevant in light of the environmental costs that may result from the conflict between Ukraine and Russia. The paradigm provided by Işk et al. (Işık et al., 2020) is essential for comprehending the impact that economic policy uncertainty might have on the demand for tourism. Reducing economic policy uncertainty to boost tourism and economic development in the area is one suggestion for resolving the environmental consequences of the Ukraine-Russian conflict. For example, the government may improve policymaking openness and predictability, and the economy could be stabilised to give companies and investors greater confidence. In addition, if sustainable tourist development techniques were implemented, it could lessen the damage to the environment caused by the conflict. In this context, "eco-friendly practises" might refer to encouraging responsible waste management, conserving natural resources, and reducing the impact of tourists on the environment. It is worth stressing that many different groups, including governments, businesses, and civil society, will have to work together to implement these suggestions. Moreover, it is essential to consider the ongoing ambiguity surrounding the conflict and its possible influence on the area

and to be flexible enough to make policy adjustments in light of evolving conditions.

Several promising avenues for future research have been identified based on the preceding discussion, all of which may expand upon the results of the present investigation. There is a need for research on the possible environmental damage and loss of biodiversity as a result of the conflict in Ukraine. This would allow for a fuller appreciation of how the war has affected the natural world. Alternatively, one may examine how previous wars have affected their environments. This might provide light on the broader topic of the environmental implications of conflicts by revealing similar trends and variances in the environmental consequences of various conflict types. The costs and advantages of various mitigation and adaptation measures, as well as the costs and benefits of various implementation scenarios, might be investigated in more depth in future studies. In addition, policy choices and the most efficient mitigation and adaptation techniques might be aided by a cost-benefit analysis of the environmental harm. The environmental, economic, and social effects of the war in Ukraine and the possible trade-offs between alternative policy alternatives might be examined using integrated assessment models in future studies.

As for the limitations, this study has focused on the environmental impacts of the conflict in Ukraine and has not considered other potential consequences of the conflict. The research may also have data availability and accuracy issues due to its reliance on cross-panel data and models. The environmental effect of the war may be complicated by other human activities in the area, which have not been taken into account in this research. Additionally, the research has not considered any environmental feedback that might affect the dispute. For instance, the war may promote changes in land usage that further worsen environmental harm, or the environmental degradation produced by the conflict may intensify the conflict. Furthermore, the research has not considered how the violence may have affected the health and wellbeing of locals. The war might have severe consequences for human health, including relocation, less access to resources, and greater exposure to environmental risks. To sum up, increased emissions of greenhouse gases and other environmental repercussions may result from the conflict, adding to global warming and other consequences of climate change. Although this study has significantly contributed to the knowledge of the environmental effects of the crisis in Ukraine, it also emphasises the need for more study to completely comprehend the conflict's repercussions and propose practical solutions for resolving the issue. A more holistic and integrated strategy may consider the conflict's effects on the environment, economy, society, and health and any feedback between these aspects. Consideration of the conflict's effects on the Paris Agreement and the Sustainable Development Goals and an examination of the advantages of low carbon may also be included.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The data is freely available at World Development Indicators published by World Bank (2022) at https://databank.worldbank.org/source/world-development-indicators.

Author contributions

Sasmoko: Conceptualization, Writing-Reviewing and Editing, Formal Analysis, Resources, Visualization, Data Curation and Validation. MI: Conceptualization, Writing-Reviewing and Editing, Formal Analysis, Resources, Visualization, Data Curation and Validation. SK: Conceptualization, Writing-Reviewing and Editing, Formal Analysis, Resources. HRK: Writing-Reviewing and Editing, Formal Analysis. HJ: Writing-Reviewing and Editing, Formal Analysis. MBM: Conceptualization, Writing-Reviewing and Editing, Data Curation and Validation KZ: Writing-Reviewing and Editing, Formal Analysis.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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