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Migration, economic drivers, and sustainability transitions: evidence from host and source countries before and after COVID-19

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ABSTRACT

This study examines whether the COVID-19 pandemic altered the relationship between economic, social, and environmental drivers and the likelihood of positive per capita net migration (PNM) across the top 25 host and 25 source countries from 2000 to 2023. Using random-effects panel probit regression, the analysis evaluates the roles of economic growth, unemployment, educational attainment, climate change, and COVID-19 cases, across the pre-COVID-19 and immediate post-pandemic periods. The findings indicate that the estimated associations differ between host and source migration systems. In host countries, economic growth, educational attainment, and COVID-19-related conditions are significantly associated with a higher likelihood of positive PNM during the immediate post-pandemic period, reflecting changing labour-market demands and recovery dynamics. In contrast, none of the examined variables is statistically significant in the source-country post-COVID-19 model, although this result should be interpreted cautiously because of the short estimation period and limited model performance. From a sustainability perspective, the findings show how global shocks may reshape migration systems, labour allocation, and resilience pathways across different development contexts. The study extends the migration push-pull framework by integrating economic, human-capital, and environmental determinants within a common empirical design and demonstrating that their associations with migration status may differ between host and source countries. The results provide policy-relevant evidence for designing adaptive migration strategies that strengthen economic resilience, support human-capital mobility, and address emerging climate-related migration pressures while contributing to Sustainable Development Goals related to decent work, reduced inequalities, and climate action.

1. Introduction

Migration has been an essential driver of global economic and social development, with significant implications for sender and recipient countries. From a sustainability perspective, migration plays a critical role in achieving multiple Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), and SDG 13 (Climate Action), by redistributing labour, skills, and adaptive capacity across regions. However, this phenomenon can be challenged in face of a worldwide pandemic such as COVID-19. In December 2019, an illness with flu-like symptoms experienced by locals in Wuhan, China, soon emerged a global concern, severely altering the movement of people and the behaviour of economies. This phenomenon transitioned into a worldwide emergency, lasting for more than three years, from March 11, 2020, to May 5th, 2023 (WHO, 2024). The height of the pandemic encountered global lockdowns and international border closures, resulting in restricted mobility in the majority of the countries, as well as increased returnee migratory pressures in others, leaving approximately 2.75 million migrants immobilised by mid-2020 [1].

The impact of this pandemic on migration across international borders can be defined and explored in many aspects. Climate-induced migration represents a key sustainability challenge, as environmental stressors increasingly reshape population mobility and resource allocation, highlighting the intersection between environmental degradation and human resilience. A vital feature to consider is the differences in impacts in the destination and originating countries, which will be referred to as host and source countries, respectively. 'Host' countries

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are primarily characterised by a positive per capita net migration (PNM), which entails a country receiving more migrants than the number of migrants that have left the country [2]. In addition to positive PNM, host countries, such as in the Gulf regions and the West, have desirable economic and social environments, relative to source countries. However, these countries, that are highly sought by labour migrants seeking better opportunities, faced significant challenges during and post-COVID-19 [3]. Despite an overall reduction in unemployment levels, the sudden decrease in migrants created labour gaps in lower-level hierarchical jobs, leading to secondary economic concerns.

In contrast, source countries, however, are characterised by a negative PNM, indicating a higher proportion of people leaving than people entering the country. The comparatively high outflow of migrants can be linked to existing economic challenges and restrictions [4, 5]. Such countries, mainly in Asia and Africa, were affected by the pandemic through surging unemployment rates and long-term reductions in remittances. Evidently, the pandemic has affected the relationship between migration and other economic and social variables differently in host and source countries.

Economic, social, and environmental conditions influence migration through interconnected push and pull mechanisms. Nevertheless, the existing evidence remains fragmented in several respects. First, many studies examine immigration or emigration separately, thereby overlooking the combined balance between migrant inflows and outflows. Secondly, economic, human capital, and environmental determinants are frequently analysed independently rather than within an integrated empirical framework. Third, relatively few studies apply a common methodology to compare host and source countries, although migration theories imply that the same determinants may operate differently across these two migration systems. Finally, limited cross – country evidence assesses whether the relationship between these determinants and migration status differed during the COVID-19 pandemic and the initial recovery period. Addressing these gaps is important because the pandemic simultaneously disrupted mobility, labour demand, education and economic activity, while its consequences were unlikely to be uniform across host and source countries.

1. What is the impact of economic growth, unemployment, climate change, educational attainment and COVID-19 on the likelihood of positive PNM in host and source countries?
2. Do the associations between these variables and the likelihood of positive PNM differ between the pre-COVID-19 (2000-2019) and immediate post-COVID-19 (2020-2023) periods for host and source countries?
3. Based on the theoretical foundations, the following two main hypotheses are defined:

H1. In host countries, increases in economic growth, climate change and educational attainment along with decreases in unemployment and COVID-19 would increase the likelihood of positive PNM in the period 2000 to 2023.

H2. In source countries, increases in economic growth and educational attainment along with decreases in unemployment, climate change and COVID-19 would increase the likelihood of positive PNM in the period 2000 to 2023.

The second research question aims to uncover whether COVID-19 has altered the determinants of positive migration in host and source countries. Therefore, the overall aim of this study is to estimate the associations and correlations between the economic variables and the likelihood of a country being a net receiver rather than a net sender, classifying PNM into a binary indicator of migration status.

1.1. Study contributions and strengths

This study makes contributions to the migration and sustainability literature. First, it integrates neoclassical migration theory, dual labour market theory, human capital theory, and environmental push-pull perspectives within a common analytical framework. Second, it examines migration using per capita net migration, thereby capturing the balance between immigration and emigration rather than considering either flow separately. Third, it applies a common empirical design to the top 25 host and top 25 source countries allowing the associations between economic, social, and environmental determinants and migration status to be compared across two functionally different migration systems. Fourth, it distinguishes the pre-COVID- 19 period from the pandemic and immediate post-pandemic periods providing early evidence of how the estimated relationships change following a major global disruption. The principal binary panel probit analysis is complemented by continuous PNM and one year lag specifications which examine the magnitude of migration balances and the temporal ordering of the relationships respectively.

These contributions extend migration push-pull theory by showing that a common global shock may produce asymmetric migration responses across host and source countries. The findings also provide a basis for differentiated migration, labour-market, education, and resilience policies rather than assuming that a uniform policy response is suitable for both migration systems.

2. Literature review

The following sections analyse key foundational migration theory, establishing common determinants of migration. It is followed by a systematic literature review, that highlights existing literature and its gaps for host and source countries.

2.1. Theoretical foundations

Various migration theories establish relationships between diverse economic factors that influence migration. To analyse whether the COVID-19 pandemic has changed these relationships, the expected relationships between migration and the economic, social and environmental variables based on the following theories, is depicted in Fig. 1.

Macroeconomic migration theories focus on the large-scale impact of economic factors such as income disparities, unemployment and labour market conditions on migration. One of the early established theories, macro neoclassical theories, reasons the cause of labour migration (the most common types of migrants) being due to differences in income between countries [6]. Reducing wage differences between the host and source country would reduce the need to migrate, thereby indicating a positive relationship and sign between income (PGDP) and migration. The World System theory also states that rather than solely by wage rates, migration can also be influenced by the expansion and development of global markets, indicating a shift to higher developed countries, which are commonly characterised by higher PGDP (Kardulias, 2008).

Furthermore, shifting perspectives to demand for labour migrants, the dual labour market theory states that migration arises from the need to keep up with the labour demands of modernising societies (Piore, 1979). Host countries often depend on low-skilled immigrants to meet labour-intensive production needs. Therefore, when there is higher unemployment rates, positive net migration is lowered due to high emigration in source countries (as a push factor) and lower immigration in host countries, indicating a negative relationship.

In terms of other economic and social factors, human capital theory comes into play. In addition to migrating for employment, people also migrate for education and skill development. Highly educated people are more likely to go to host countries that can offer higher returns for their capabilities (Borjas, 1999) indicating a positive relationship with education and migration. Simultaneously, a general increase in

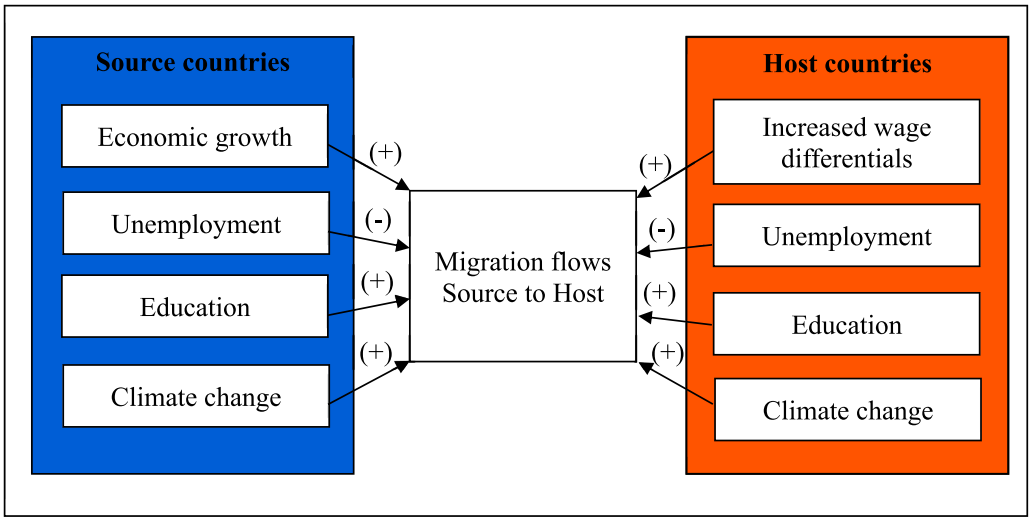


Fig. 1. Migration conceptual framework.
Note: Figure shows the relationships between economic, social and environmental variables with migration, for source and host countries. Source: Authors' composition.

educational attainment would reduce emigration to source countries. Furthermore, in the rise of climate change and sustainable development, environmental push and pull factor theories indicate that undesirable natural disasters due to rising mean temperatures cause forced displacement or migration in source and host countries.

Whilst these theories analyse the impact of various factors that correlate with positive PNM, the relationship between migration and economic growth is often interconnected resulting in bi-directional relationships, such that increases in positive PNM can in turn be correlated with higher economic growth, educational attainment, unemployment rates and climate change. However, for the focus of this study, the impact of the drivers of net migration are considered.

2.2. Empirical literature

Host countries are the countries that experience higher rates of positive net migration, in comparison to negative net migration rates, due to the availability of pull factors such as financial stability, higher wages, and social benefits. As per the studies conducted based on host countries in Europe, North America, and Oceania, PGDP is identified to have a positive impact on PNM. This is due to countries with higher PGDP, which are known to provide better standards of living and opportunities to grow in comparison to countries with lower PGDP ([7]; Morley, 2006; Strzelecki, Growiec, & Wyszyński, 2022). Recent evidence from South Asian countries further indicates that higher GDP per capita strengthens a country's capacity to invest in infrastructure, environmental protection and institutional development, thereby supporting broader sustainable development outcomes [8]. Similarly, EDA is considered to have a positive impact on PNM [9]. This is due to countries with better education systems being able to provide a variety of courses that in high -demand (Anna et al., 2023; Istudor, Dinu, Gogu, Prada, & Petrescu, 2020). Also, there are other studies that show the same impact due to host countries having the ability to effectively utilise more skilled and educationally qualified individuals ([2,10]; Postula & Radecka-Moroz, 2020; [11]). However, due to the rise in immigrants, there can be adverse effects as well, such as a rise in competition levels and a reduction in wages and can also lead to a decrease in PGDP.

Conversely, UMP in host countries is identified as having a negative impact on PNM (Boubtane, Coulibaly, & Rault, 2013). This is due to immigrants not arriving in these countries after seeing increasing unemployment, rising labour market competition, and lacking the skills and knowledge required to fill the labour market gaps (Noja, Cristea, Yüksel, Pânzaru, & Drăcea, 2018; Serban, Aceleanu, Dospinescu, Tirca, & Corti, 2020). However, unemployment in host countries can take place due to a lack of employees available to take part in jobs that require fewer skills and qualifications, for example, domestic employees. In such cases, people with fewer skills and qualifications are more likely to migrate to these countries in search of better wages than what they receive in their source countries.

As for CVD, it is known to hurt PNM or human mobility in terms of host countries [3]. This is because most immigrants had to leave due to losing their jobs. In this case, the host countries' labour gaps increased rapidly, leading to a decrease in PGDP [12]. Moreover, it led to an increase in the vulnerability of the immigrants who were working in jobs that required fewer skills and qualifications (Olha, Nataliia, Oksana, Ulyana, & Halyna, 2021). Migrants, to some extent, started avoiding host countries, which were highly affected by CVD, even though those countries were ready to pay higher wages and better opportunities (Smith & Wesselbaum, 2020). However, host countries were able to recover faster from the pandemic in comparison to the source countries. Therefore, people started immigrating in terms of finding better opportunities once the pandemic slowed down in spreading.

Source countries are countries that experience higher rates of negative PNM in comparison to positive PNM due to the availability of economic push factors such as poverty and limited access to growth. Recent evidence suggests that the economic role of migration differs substantially across income groups, with net migration appearing to have a stronger influence on economic growth in lower-income countries than in high-income countries, partly because of their greater dependence on remittances and migrant-related income flows [13].The studies conducted based on intracontinental migration show that there are source countries that do attract migrants as well due to their slightly higher PGDP. People migrate to these countries due to not having sufficient resources to support them in migrating to high-income countries [4,5]. However, even though rising PGDP reduces emigration, an increase in EDA leads to emigration due to a lack of opportunities, high competition, and low wages (Lanati & Thiele, 2024). Nevertheless, if return migration takes place, the source countries will be able to reduce the negative impact of emigration (Huynh & Vo, 2023; Reina et al., 2024). Recent global evidence further shows that the relationship between Per Capita Net Migration (PNM) and economic growth varies across income groups, with migration contributing to growth through remittances, labour supply and the transfer of skills and knowledge, particularly in lower-middle-income countries [14].However, source

countries can have a positive effect of return migration only if they have adequate resources that can effectively utilise the skills and knowledge brought into the countries. Recent evidence from South Asia shows that political stability and the rule of law strengthen sustainable development outcomes, while weak governance can constrain policy implementation, investment, and social resilience [15]. In migration contexts, these institutional conditions may determine whether source countries can retain skilled workers, absorb return migrants, and convert returned human capital into sustainable economic benefits.

Regarding source countries, CVD harms PNM mainly due to travel restrictions among both source and host countries (Martin & Bergmann, 2021) and also the reduction of benefits the source countries received through migrants. The majority had to return not only by losing jobs and their source of income but also due to fearing the pandemic (Inegbedion, 2021; Phuyal, Bhattarai, & Acharya, 2024; [16]). On the other hand, some studies consider CVD to have a positive impact on return migration in the source countries due to people coming back with what they learnt (Withers, Henderson, & Shivakoti, 2022). However, this can be possible only in the long run due to source countries taking more time to recover from the pandemic. Some studies also show that CVD allows the source countries to make more investments towards improving healthcare (Aduhene & Osei-Assibey, 2021). However, due to this situation, and the pandemic, the source countries had to depend more on other countries and world organisations even when those countries or organisations were unable to help with all the requirements fully.

Moreover, when considering CVD in terms of source and host countries together, it shows a negative impact mainly on countries that are highly dependent on migrant employees and countries that are highly dependent on benefits they receive through migrants abroad [17]. However, as CVD largely impacted on the continuity of life, it negatively affected all countries. Yet, host countries were able to mitigate the effects more quickly than the source countries and allow more immigrants to come in, which led source countries to enjoy the benefits soon.

On the other hand, as for the impact of CLC on PNM, host countries are known to have a positive effect, while source countries are known to negatively influence PNM. Recent evidence from the East Asia-Pacific region demonstrates that the sustainability implications of energy and environmental conditions are stage-dependent, reflecting differences in development levels, energy structures, infrastructure readiness, and institutional capacity [18]. These structural differences also suggest that climate-related migration pressures may not operate uniformly across host and source countries. As per the studies conducted, it shows that host countries have a positive effect because they can accommodate immigrants in comparison to source countries while allowing them to have better opportunities, which can also lead the source countries to benefit in the end. However, source countries are known to have a negative impact because people will emigrate to a safe place instead of remaining in an environmentally threatened location ([19,20]Marchiori & Schumacher, 2011). However, when it comes to CLC, it not only takes place in source countries, but there are also host countries which are being affected by CLC, such as the USA, Canada, and Australia. These countries are known to have rising temperatures, which has led to wildfires to take place and extreme floods along with hurricanes.

As per past studies, most of have analysed the impact of various variables on migration in terms of immigration and emigration separately, which has led to the analysis of source and host countries separately as well. Moreover, more studies are lenient towards identifying how migration impact the other variables. Most importantly, there are fewer studies that have statistically analysed the effects of CVD. Studies are mainly focused on providing policy implications to prepare countries to face such pandemics while additionally mentioning that CVD primarily affects human mobility. Additionally, the studies lack statistical comparisons to understand how migration was before and after CVD.

3. Data and methodology

3.1. Data, variables and sources

This study employs the latest panel data from 2000 to 2023, resulting in 1,200 observations for 25 host countries and 25 source countries. The secondary data sources and primary variables of the study are detailed in Table 1.

The final data set used in the analysis is included in the S1 Appendix and Table 2 details the country list incorporated in the study along with their classification category.

The country classification was based on average per capita net migration over the complete 2000- 2023 period. Rather than total migrant numbers or population size, countries were ranked according to this measure subject to the availability of equal-sized comparison groups for the dependent and explanatory variables. The 25 countries with the highest average PNM values were classified as host countries, while the 25 countries with the lowest average PNM values were classified as source countries. The use of a per capita measure permits comparisons across countries with substantially different population sizes and prevents highly populated countries from dominating the classifications solely because of their absolute migration numbers. The restriction to 25 countries in each category was adopted to obtain equal sized comparison groups while maintaining consistent data coverage over the study period. Accordingly, India and China were not manually excluded; they did not fall within either selected group under the study's average per capita net migration ranking and data selection criteria. Therefore, the findings represent countries with the most pronounced per capita host and source characteristics rather than the entire global population.

Further, Fig. 2, outlines the six-step process followed during the research.

During step four, the researchers employed multiple imputation, which is a method commonly used [21–23], for imputing missing values in the collected data. Table 3 details the total of 3 missing data points which were predicted.

Missing data were minimal (0.25%) and imputation for incomplete variables were conducted using chained equations (m=20 imputations, seed=12345) and estimates were pooled using Rubin's rules. With negligible missingness, imputation method has minimal impact on substantive conclusions.

Table 1
Data sources and variables.

Variable	Measure	Measuring unit	Source
Migration	PNM (Per capita net migration)	Number of net migrants per person	World Bank World Bank
Economic growth	PGDP (Per capita gross domestic, PPP (constant 2021 international $))	United States Dollars ($)	World Bank
Unemployment	UMP (Unemployment, youth total (% of total labour force ages 15-24) (modeled ILO estimate))	Percentage of total labour force	World Bank
Climate change	CLC (Mean temperature change of meteorological year)	Degree Celsius	International Monetary Fund
Educational attainment	EDA (Mean-years-of-schooling-long-run)	Average years	Our World in Data
COVID-19	CVD (Total confirmed cases of COVID-19 per million people)	Number of confirmed cases per million people	Our World in Data

Source: Authors' composition.

Table 2
Country classification.

Category	Country	Country Code
Host	Australia	AUS
Host	Austria	AUT
Host	Belgium	BEL
Host	Belize	BLZ
Host	Canada	CAN
Host	Cyprus	CYP
Host	Denmark	DNK
Host	Germany	DEU
Host	Hungary	HUN
Host	Iceland	ISL
Host	Ireland	IRL
Host	Italy	ITA
Host	Jordan	JOR
Host	Kuwait	KWT
Host	Luxembourg	LUX
Host	Malaysia	MYS
Host	Malta	MLT
Host	New Zealand	NZL
Host	Norway	NOR
Host	Sierra Leone	SLE
Host	Spain	ESP
Host	Sweden	SWE
Host	Switzerland	CHE
Host	United Kingdom	GBR
Host	United States	USA
Source	Albania	ALB
Source	Bangladesh	BGD
Source	Dominican Republic	DOM
Source	El Salvador	SLV
Source	Eswatini	SWZ
Source	Fiji	FJI
Source	Guatemala	GTM
Source	Guyana	GUY
Source	Haiti	HTI
Source	Jamaica	JAM
Source	Lesotho	LSO
Source	Libya	LBY
Source	Morocco	MAR
Source	Myanmar	MMR
Source	Nepal	NPL
Source	Nicaragua	NIC
Source	Pakistan	PAK
Source	Paraguay	PRY
Source	Peru	PER
Source	Senegal	SEN
Source	Sri Lanka	LKA
Source	Syrian Arab Republic	SYR
Source	Uganda	UGA
Source	Uruguay	URY
Source	Zimbabwe	ZWE

Source: Authors' composition.

3.2. Panel probit regression

This study employed a panel probit regression model to analyse the impact of EDA, CLC, PGDP, UMP, and CVD on PNM across a panel of countries from 2000 to 2023. This methodology is commonly used in healthcare [24], economics [25,26], and finance (H [27].) domains. Accordingly, the formulated panel probit model is represented in Eq. 1.

$$PNM_{it} = \beta_0 + \beta_1 \mathrm{PGDP}_{it} + \beta_2 \mathrm{CLC}_{it} + \beta_3 \mathrm{EDA}_{it} + \beta_4 \mathrm{UMP}_{it} + \beta_5 \mathrm{CVD}_{it} + \epsilon_{it} \quad (1)$$

Where, PNM_{it} represents the latent variable for net migration for unit i at time t, while ϵ_{it} represents the error term. The probability that $PNM_{it} = 1$ can be expressed as the Eq. 2 where ϕ is the cumulative distribution function of the standard normal distribution, where x_{it} represents all the independent variables.

$$P(PNM_{it} = 1 \mid x_{it}) = \phi(\beta_0 + \beta_1 \mathrm{PGDP}_{it} + \beta_2 \mathrm{CLC}_{it} + \beta_3 \mathrm{EDA}_{it} + \beta_4 \mathrm{UMP}_{it} + \beta_5 \mathrm{CVD}_{it} + \epsilon_{it}) \quad (2)$$

The study defines 'Host' countries as those primarily characterised by a positive PNM (receiving more migrants than departing), while 'Source' countries are characterised by a negative PNM (more people leaving than entering). The dependent variable, PNM_{it} it is defined as:

$$PNM_{it} = \begin{cases} 1 \text{ if } PNM_{it} \geq 0 \\ 0 \text{ if } PNM_{it} < 0 \end{cases}$$

This binary structure directly measures the likelihood of positive per capita net migration, which serves as the operational measure to distinguish between these two functional states. Further, the use of panel probit regression is chosen specifically because this methodology is particularly suited for this analysis, due to its ability to handle binary outcome variables. The transformation aligns the analytical framework with the research questions regarding the classification of countries as net receivers or net senders, rather than predicting the exact volume of flow.

The model was estimated using random-effects probit regression in STATA. To assess how COVID-19 changed the impact of the independent variables on migration, two distinct periods were analysed: Prior to and post-COVID-19. Analysing the likelihood of positive PNM allows to reveal differences in the behaviour of migration drivers in host and source countries before (2000 to 2019) and after (2020 to 2023) COVID-19, providing insights tailored for policy recommendations to aid sending and receiving countries in leveraging migratory policies.

3.3. Model choice and identification limits

This subsection outlines the rationale for the selected model, its underlying assumptions, identification limitations, and the robustness considerations applied in the study.

3.3.1. Probit specification

The Panel Probit Model was particularly suited for this analysis, due to its ability to handle binary outcome variables, while accounting for unobserved heterogeneity across entities. Using data from multiple periods for the same subjects, the model can isolate the effects of independent variables more accurately than pure cross-sectional or time-series analyses. Further, the probit regression model provides marginal effects of each variable, indicating how a one-unit change in an independent variable affects the outcomes.

3.3.2. Random-effects framework

Random-effects panel probit was selected because the dependent variable is binary and the analysis requires both within-country and between-country variation over time. The random-effects framework accounts for unobserved time-invariant country heterogeneity while retaining cross-country information that is central to the comparison of host and source migration systems. Nevertheless, the estimator assumes that the country-specific random effect is uncorrelated with explanatory variables. Recognising the restrictiveness of this assumption, the results are interpreted as conditional associations rather than causal effects. Continuous PNM and one-year-lagged specifications are additionally reported as robustness checks to assess sensitivity to the measurement of migration and the contemporaneous timing of the explanatory variables.

3.3.3. Key assumptions

The random-effects probit estimator assumes strict exogeneity and independence between country-specific effects and the explanatory variables. These assumptions cannot be fully verified using

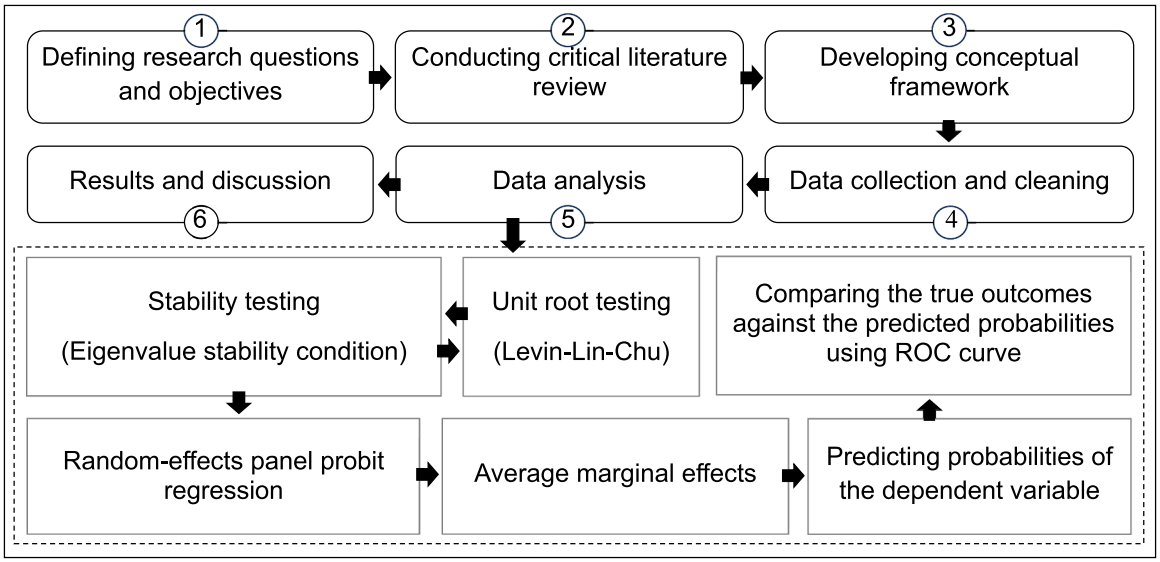


Fig. 2. Data analysis flow diagram.
The Fig. 2 shows the research process and data analysis methods including data cleaning, stationarity and stability testing and panel probit regression. Source: Authors' composition.

Table 3
Missing data.

Category	Country	Data missing variable	Data missing year
Source	Jamaica	PNM	2020
Source	Haiti	CLC	2000
Host	Sierra Leone	CLC	2000

Source: Authors' composition.

observational data and may be violated by reverse causality or omitted time-varying factors. The estimates are therefore interpreted as associations, while one-year-lagged explanatory-variable models are used to improve temporal ordering and reduce, although not eliminate, concerns regarding contemporaneous simultaneity.

3.3.4. *Identification limits*

Our identification relies on temporal and cross-national variation in economic variables across 24 years and 25 countries. Critical limitations include potential omitted policy variables, inability to estimate migration magnitudes, and possible selection bias in host/source classification. The strict exogeneity assumption may be violated if unobserved institutional factors correlate with measured economic conditions. The lagged-variable robustness analysis improves temporal ordering but does not fully resolve these identification concerns.

4. Results

The following sections contain a constructive descriptive analysis, followed by the panel probit regression model outputs.

4.1. *Descriptive analysis*

Descriptive statistics, historical trends, and the results of the panel probit regression are discussed in the following section. Fig. 3 illustrates the distribution of the variables using violin plots, and the comprehensive summary of the descriptive statistics is detailed in the S2 Appendix.

Overall, the Fig. 3 reveal a clear distinction between host and source panels. As shown in Fig. 3a, PNM values in host countries are more optimistic, indicating a comparative inflow of migrants. On the other hand, PNM values in source countries are more pessimistic, with most of the values concentrated at the lower end highlighting the migration pressures exist in these countries.

According to the Fig. 3b, the host countries exhibit higher level of economic development reflecting economic strength and stability [7], while in source countries PGDP concentrated toward the lower end of the distribution, indicating economic inequalities [11].

UMP rate generates more of a contrast between these two groups. As depicted in Fig. 3c, the unemployment figures for the host countries show moderate dispersion around lower levels of unemployment, which is evidence of more stable labour markets. However, the high variability in the source country appears in unemployment rates, placing those source countries at significant economic vulnerability and an inconsistent labour market condition.

In Fig. 3d, similarities between host and source countries are also illustrated with the effects of CLC. Temperature deviations of the host countries are wider; therefore, they are facing more challenging problems in climate variability. Although source countries display a narrower range of temperature changes, many remain highly vulnerable because of limited adaptive capacity, infrastructure and institutional resources.

Furthermore, EDA is another area of pronounced differences. Fig. 3e implies that host country economies are highly compact with minimal variation around the higher-end values that indicate well-developed educational systems. In contrast to source countries, there is a more dispersed EDA distribution indicating a much more extensive range of academic outcomes and more significant disparities in access to education.

Finally, the distributions of CVD between the two groups are substantial. As represented in Fig. 3f, the host countries are highly variable, with many extreme COVID-19 cases while the source country panel stay close to zero.

The area charts in Fig. 4 illustrate the historical trends of each variable. The charts were created using the mean values of each variable from 2000 to 2023.

The contrasting trends in PNM between host and source countries can be observed in Fig. 4a. Positive PNM values are consistently found in host countries and persisting negative PNM values are exhibited in source countries, showing ongoing emigration pressures. Post 2020, the PNM trends for host and source countries have reached zero. This relationship is supported by findings from the literature, which noted shifts in migration patterns during the pandemic, with PNM moving

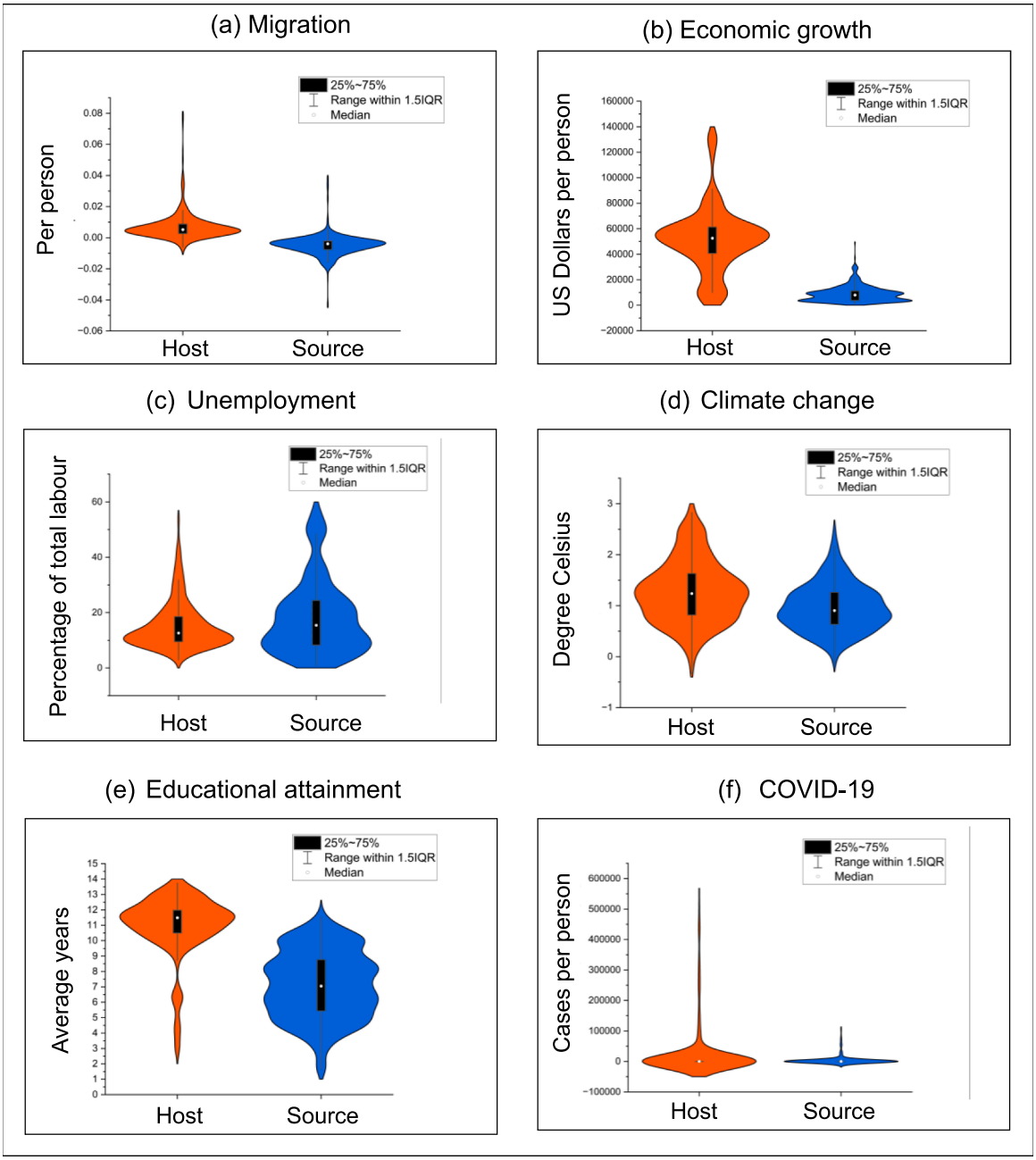


Fig. 3. Distribution of the variables.
The Fig. 3 displays violin plots for the six variables, distinguishing the orange plot for host country distributions and blue plot for source country distributions. Source: Authors' composition utilising OriginLab [28].

away from urban centres toward regional areas due to changing economic conditions and pandemic-related restrictions [29,16].

PGDP trends shown in Fig. 4b indicates stark economic disparities between host and source countries. Source countries have experienced modest growth, whereas host countries' trend of increasing share in the past 2008 has been consistent, especially during the 2008 financial crisis. The widening economic gap is a push factor of equal importance as those from lower-income nations migrate to seek opportunities abroad [9]. While high return migration due to the spread of the pandemic led to a reduction in the PGDP of the host countries at the end of 2019 [12], studies have shown that areas with high immigrants to endure and recover fast from economic turbulence faster [30]. This can be true because during the COVID-19 period, the host countries experienced a temporary downward PGDP trend followed by a strong upward trend while source countries made minimal improvements.

Source countries maintain higher unemployment rates than host countries, potentially because many young people are unable to obtain employment matching their educational qualifications. This structural difference highlights the relative labour-market stability of host countries and the employment challenges faced by source countries. This can be due to many young people finding it difficult to find employment opportunities suitable for their education qualifications. This structural difference emphasises host countries' stabilisation and source countries' problems.

Fig. 4d reveals another layer of complexity in migration dynamics. A steady upward trend in CLC in host countries and a lower but rising trend in source countries can be observed. In both panels, decisions over time are markedly more influenced by climate change as people search

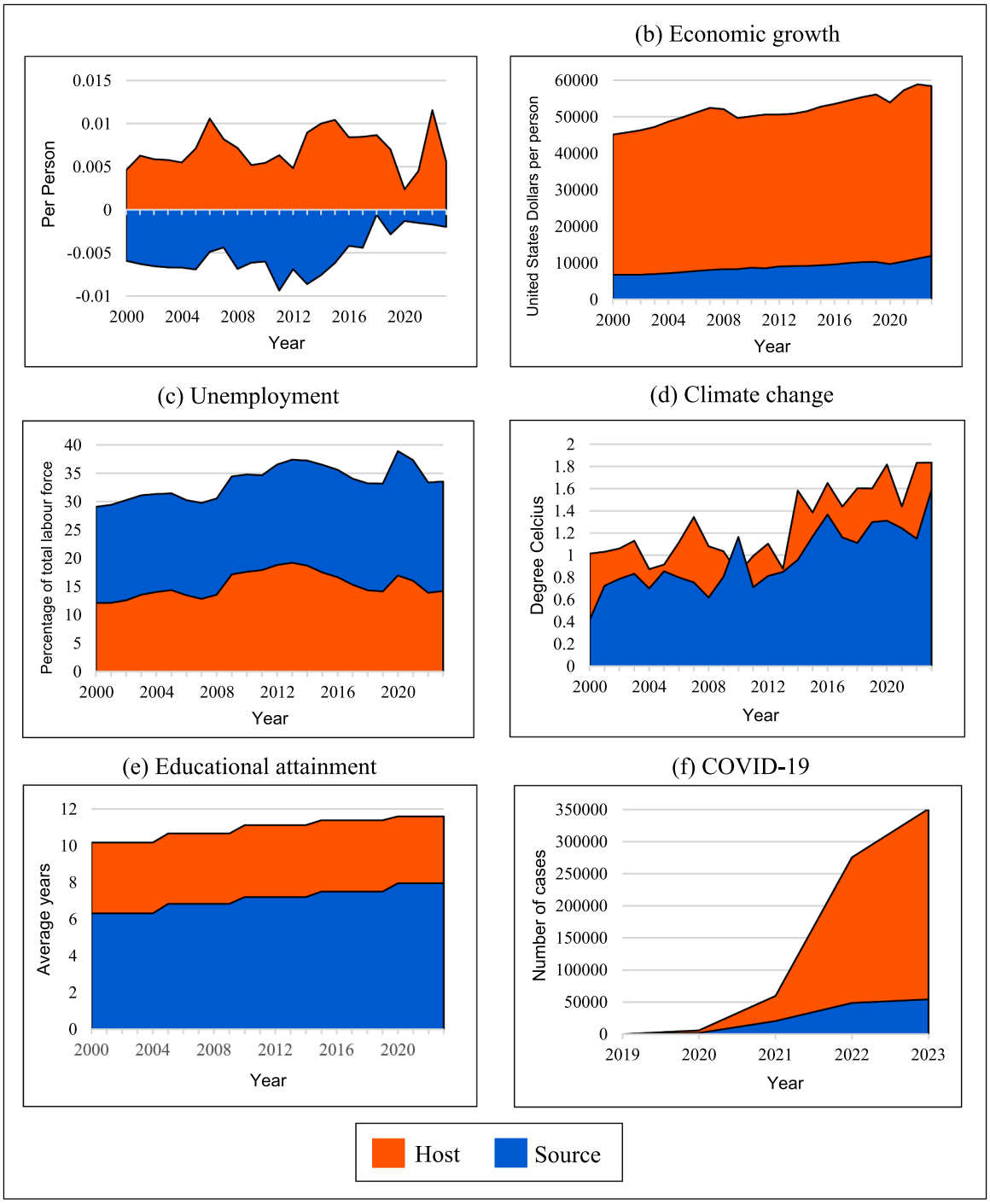


Fig. 4. Historical trend of the variables.
The Fig. 4 contains six area charts for the six variables, distinguishing the orange plot for host country historical trends and blue plot for source country historical trends. Source: Authors' composition.

for more stable environments [11]. It has become clear that environmental factors are becoming increasingly important drivers of migration in vulnerable areas.

In Fig. 4e, host countries outperform source nations in EDA, indicating that disparities in access to quality education abounds. The high EDA trends in host countries suggest that EDA is a determinant of migration.

As shown in Fig. 4f, the host countries have a disproportionately and more significant share of COVID-19 cases compared to source countries, perhaps due to their population density. This highlights the need for adaptive migration policies, as paying attention to the impact of the pandemic across different regions is necessary.

4.2. *Stationarity and stability testing*

Before the panel probit regression analysis, all the variables were tested for stationarity and stability to ensure that the models identify consistent relationships and trends, leading to reliable estimations. The LLC unit root stationarity test results are detailed in the S3 Appendix and the eigenvalue stability test results are detailed in S4 Appendix. The

summary of test results is presented in Table 4.

The nonstationary and/or unstable variables were differenced to achieve stationarity and stability.

4.3. Host country estimations pre-COVID-19

The following sections highlight the panel probit regression results for four main models, host countries and source countries regression results pre and post-COVID-19. Based on the theoretical framework and literature review for the host countries' panel probit regressions, the alternative hypothesised outcomes are as follows in Table 5.

In host countries, a positive correlation from PGDP, CLC, EDA and a negative correlation from UMP, and CVD is hypothesised on the likelihood of positive PNM. First, a model of the panel probit regressions was run for the top 25 host countries to assess the likelihood of PNM being positive. Results tabulated in Table 6 were obtained for 2000 to 2019, which is classified as the pre-COVID-19.

Beginning with the first variable, a positive relationship was hypothesised between PGDP and positive PNM. As hypothesised, the results and estimated coefficient display a positive relationship, reflecting the neoclassical theories in the theoretical framework. A 1 unit increase in the ΔPGDP increases the probability of PNM being positive by 0.001%.

Furthermore, the remaining variables did not produce statistically significant results. The variable UMP produced positive correlations as opposed to the negative correlations hypothesised. The marginal effects show a 1 unit increase in the ΔUMP increases the probability of positive PNM by 0.031%. Moreover, for CLC, a 1-unit change in ΔCLC increases the likelihood of PNM being positive by 0.151%. Whereas for EDA, a 1 unit increase in EDA increases the likelihood of positive PNM by 1.41%.

4.4. Host country estimations post-COVID-19

The second model examines whether the COVID-19 pandemic alters the relationship between economic variables and migration. Despite the post-COVID-19 period of 2020 to 2023 losing a year due to differencing, it still serves as a valid period to analyse any short-term shifts in the likelihood of positive PNM in response to the pandemic. While it may be too early to predict the long-term alterations to the dynamics of these relationships with PNM, the aim is to examine whether any significant variations have occurred in this short period after COVID-19. The results are shown in Table 7.

Notably, there are differences in the economic variables' statistical significance and marginal effects after the pandemic. The variable PGDP remains significant, post-pandemic, with a slightly higher marginal effect, where in 1 unit increase in ΔPGDP, increases the likelihood of positive PNM by 0.002%. When it comes to UMP post-COVID-19, marginal effects have increased, wherein a 1 unit increase in ΔUMP rates increases the probability of PNM being positive by 1.61%.

Moreover, the statistically significant sign of the estimated coefficient of the CVD variable opposes the negative relationship hypothesised between CVD and the likelihood of positive PNM. Here, a 1 unit increase CVD increases the likelihood of positive PNM by 0.00006%.

Table 4
Stationarity and stability summary.

Host countries	PGDP		UMP	●	CLC	●	**EDA**	● ○
	dPGDP	● ○	**dUMP**	● ○	**dCLC**	● ○		
Source countries	PGDP		**UMP**	● ○	CLC	●	**EDA**	● ○
	dPGDP	● ○			**dCLC**	● ○		

Note: The sign ● indicates stationarity, and ○ indicates stability.
Source: Authors' composition.

Table 5
Hypotheses for host countries.

Hypothesis number	Alternative hypothesis
Hypothesis 1	As PGDP increases, the likelihood of PNM being positive increases.
Hypothesis 2	As UMP increases, the likelihood of PNM being positive decreases.
Hypothesis 3	As CLC increases, the likelihood of PNM being positive increases.
Hypothesis 4	As EDA increases, the likelihood of PNM being positive increases.
Hypothesis 5	As CVD increases, the likelihood of PNM being positive decreases.

Source: Authors' composition.

Additionally, the CLC variable marginal effects increase post-COVID-19. The coefficients indicate a positive relationship, wherein a 1 unit increase in ΔCLC increases the likelihood of PNM being positive by 0.731%.

Interestingly, educational attainment variable EDA has become significant post-COVID-19, and has the highest marginal effects, wherein a 1 unit change in EDA would increase the likelihood of positive PNM by 2.25%. Therefore, post-COVID-19, the key predictors of positive PNM are educational attainment, average COVID-19 cases and economic growth in host countries.

4.5. Source country estimations pre-COVID-19

Based on the theoretical framework and literature review, the alternative hypothesised results for the source countries panel probit regressions are in Table 8.

Here, a negative relationship can be hypothesised among UMP, CLC and CVD variables, whereas a positive relationship is anticipated for PGDP and EDA. The panel probit estimations presented in Table 9 contains the results for the 25 source countries selected from 2000 to 2019, before COVID-19.

Prior to COVID-19, the variable of economic growth is the only variable that has a statistically significant effect on the probability of positive PNM, wherein, 1 unit increase in ΔPGDP, increases the likelihood of positive PNM by 0.002%, which is comparatively higher to host countries. The variable UMP confirms a negative correlation yet statistically insignificant result, having a marginal effect of -0.011%. CLC do not have the expected signs and are not statistically significant, wherein a 1 unit increase in ΔCLC increases the likelihood of positive PNM by 1.309%. Moreover, EDA, indicates a positive relationship with PNM, wherein a one-year increase in educational attainment would increase the probability for positive PNM by 1.57%.

4.6. Source country estimations post-COVID-19

Table 10 highlights the panel probit regressions in the fourth and final model for the 25 source countries after COVID-19.

After the pandemic, none of the explanatory variables is statistically significant in the source-country model. Although the estimated coefficients for ΔPGDP, UMP, CVD, ΔCLC and EDA are negative, these estimates should not be interpreted as evidence of reliable negative relationships. The directions and marginal effects are descriptive estimates only and may reflect the short post-pandemic period, limited variation in migration status, heterogeneous recovery conditions and omitted institutional or migration-policy factors.

4.7. Robustness analysis using continuous per capita net migration

The principal analysis uses random-effects panel probit regression to estimate the likelihood that PNM is positive. As a complementary

Table 6
Panel probit estimation results for host countries before COVID-19.

Variable	Estimated coefficient	Robust standard error	95% Confidence interval		Marginal effect (%)
dPGDP	**0.00017***	0.00010	-0.00002	0.00036	**0.001**
dUMP	0.00380	0.03005	-0.05509	0.06270	0.031
dCLC	0.01882	0.12260	-0.22147	0.25912	0.151
EDA	0.17602	0.11323	-0.04592	0.39795	1.414
Constant	0.48074	1.25382	-1.97671	2.93818	
Log likelihood	-95.42				
Number of observations	475				

Note: The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. The CVD variable is excluded, as this model tests for the pre-COVID-19 period (2000 to 2019).
Source: Authors' composition.

Table 7
Panel probit estimation results for host countries after COVID-19.

Variable	Estimated coefficient	Robust standard error	95% Confidence interval		Marginal effect (%)
dPGDP	**0.00037*****	0.00011	0.00015	0.00059	**0.002**
dUMP	0.38017	0.23628	-0.08293	0.84328	1.611
CVD	**0.00001***	8.10×10^{-6}	-1.76×10^{-6}	0.00003	**0.00006**
dCLC	0.17246	0.22791	-0.27423	0.61914	0.731
EDA	**0.53250***	0.30790	-0.07097	1.13597	**2.257**
Constant	-4.99448	2.84650	-10.57351	0.58454	0.002
Log likelihood	-10.85				
Number of observations	75				

Note: The significance level of 1%, 5% and 10% is denoted by ***, **, and * respectively.
Source: Authors' composition.

Table 8
Hypotheses for source countries.

Hypothesis number	Alternative hypothesis
Hypothesis 6	As PGDP increases, the likelihood of PNM being positive increases.
Hypothesis 7	As UMP increases, the likelihood of PNM being positive decreases.
Hypothesis 8	As CLC increases, the likelihood of PNM being positive decreases.
Hypothesis 9	As EDA increases, the likelihood of PNM being positive increases.
Hypothesis 10	As CVD increases, the likelihood of PNM being positive decreases.

Source: Authors' composition.

robustness test, random-effect panel regressions were estimated using continuous PNM as the dependent variable. Unlike the binary specification, the continuous measure retains information on the direction and magnitude of the migration balance. The continuous and binary models therefore examine related but distinct dimensions of migration, and their coefficient magnitudes should not be compared directly. The results are reported in Table 11.

For host countries before COVID-19, the coefficient of ΔUMP is negative and statistically significant at the 5% level, while ΔPGDP, ΔCLC and EDA are statistically insignificant. This suggests that increasing unemployment is associated with a reduction in the magnitude of the host-country migration balance during the pre-pandemic period.

For host countries during 2021–2023, COVID-19 cases are positively associated with continuous PNM at the 10% significance level. The coefficients of ΔPGDP, ΔUMP, ΔCLC and EDA are statistically insignificant. The positive COVID-19 coefficient should be interpreted cautiously because its magnitude is very small and the short period may capture border reopening, return flows and recovery-related migration rather than the direct effect of infections.

For source countries before COVID-19, ΔPGDP is positively associated with continuous PNM at the 1% significance level, while UMP, ΔCLC and EDA are statistically insignificant. In the source-country model for 2021–2023, ΔPGDP is negative and statistically significant at the 1% level, whereas UMP, COVID-19 cases, ΔCLC and EDA are statistically insignificant. This indicates that higher changes in economic growth are associated with a more negative continuous migration

Table 9
Panel probit estimation results for source countries before COVID-19.

Variable	Estimated coefficient	Robust standard error	95% Confidence Interval		Marginal effect (%)
dPGDP	**0.00028*****	0.00010	0.00008	0.00048	**0.002**
UMP	-0.00127	0.02889	-0.05790	0.05536	-0.011
dCLC	0.15434	0.09920	-0.04009	0.34877	1.309
EDA	0.18586	0.21877	-0.24293	0.61464	1.576
Constant	-3.97291	1.66562	-7.23747	-0.70834	
Log likelihood	-92.93				
Number of observations	475				

Note: The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively. CVD variable is excluded, as this model tests for pre-COVID-19 period (2000 to 2019).
Source: Authors' composition.

Table 10
Panel probit estimation results for source countries after COVID-19.

Variable	Estimated coefficient	Robust standard error	95% Confidence Interval		Marginal effect (%)
dPGDP	-0.0005102	0.0004903	-0.0014713	0.0004508	-0.003
UMP	-0.0303164	0.0431236	-0.1148371	0.0542043	-0.200
CVD	-6.11×10^{-6}	0.0000194	-0.0000441	0.0000319	-0.00004
dCLC	-0.1697462	0.6904976	-1.523097	1.183604	-1.118
EDA	-0.2010532	0.2791425	-0.7481626	0.3460561	-1.324
Constant	-0.765206	3.886353	-8.382318	6.851906	
Log likelihood	-20.214303				
Number of observations	75				

Note: The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.
Source: Authors' composition.

Table 11
Robustness Check: Random-Effects Panel Regression on Continuous PNM.

Variable	Host pre- COVID-19	Host 2021-2023	Source pre-COVID-19	Source 2021-2023
dPGDP	-0.000000342	0.000000144	**0.000003657*****	**-0.000000466*****
	(0.000000401)	(0.000000159)	(0.000000727)	(0.000000120)
dUMP	**-0.000312202****	-0.000833658		
	(0.000138581)	(0.000634450)		
dCLC	0.000105575	-0.000127306	0.001050960	-0.000519144
	(0.000299739)	(0.001714535)	(0.000810176)	(0.000598958)
EDA	-0.000544993	-0.000861213	**-0.000526401***	-0.000054464
	(0.000674255)	(0.001565817)	(0.000271911)	(0.000468196)
CVD		**0.000000009***		-0.000000005
		(0.000000005)		(0.000000009)
UMP			-0.000101894	0.000030650
			(0.000093390)	(0.000068657)
_cons	0.013528232*	0.014088275	-0.001116777	-0.001326723
	(0.008106729)	(0.017791358)	(0.002337148)	(0.003478314)
Observations	475	75	475	75

Note: Standard errors are reported in parentheses. Based on the stationarity results PGDP and CLC enter all models in first differences. UMP enters the host country models in first differences and the source country model in the levels. EDA and CVD are retained in levels. Applying first differences reduces the usable immediate post-pandemic period to 20210-2023.
The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.
Source: Authors' composition.

balance during the immediate post-pandemic period, although the finding is based on a short estimation window.

Overall, the continuous-PNM models provide only partial confirmation of the binary-probit findings. The consistency of the pre-COVID-19 source-country GDP result strengthens confidence in that relationship. However, differences in several host-country results demonstrate that conclusions depend partly on whether migration is measured as net-receiver status or as the magnitude of the migration balance. The continuous results should therefore be viewed as complementary rather than directly comparable estimates.

4.8. Robustness analysis using lagged explanatory variables

To improve temporal ordering and reduce concerns regarding contemporaneous simultaneity, an additional random-effects panel probit model was estimated using one-year-lagged explanatory variables. Under this specification, explanatory conditions observed in year t-1 are used to estimate the probability of positive Per Capita Net Migration (PNM) in year t. Lagging the explanatory variables does not completely eliminate endogeneity arising from omitted factors or persistent reverse causality. However, it reduces the possibility that current migration status directly determines contemporaneous explanatory conditions. Because of the one-year lag and the differencing of selected variables, the immediate post-pandemic models cover the period from 2021 to 2023. The results are presented in Table 12. Additional robustness estimates based on one-year-lagged PGDP specifications are reported in S6 Appendix.

One-year lagged variables are denoted by L. Applying one-year lags and first differences reduce the pre-COVID-19 samples to 450 observations.

For host countries before COVID-19, lagged dUMP (L.dUMP) was negative and statistically significant at the 10% level. The coefficients of lagged ΔPGDP (L.PGDP), lagged dCLC (L.dCLC) and lagged EDA (L.EDA) were statistically insignificant.

During the immediate post-pandemic years, L.dPGDP and L.dCLC were positive and statistically significant at the 10% level, while L.EDA was positive and significant at the 5% level. These findings indicate that preceding period economic growth, climatic conditions and educational attainment were associated with a higher probability of positive PNM in host countries. Lagged unemployment and CVD cases were statistically insignificant.

For source countries before COVID-19, L.dPGDP was positive and statistically significant at the 1% level, while the remaining lagged explanatory variables were statistically insignificant. During the immediate post-pandemic years, none of the lagged explanatory variables was statistically significant in the source-country model.

Overall, the lagged-variable results provide partial support for the principal specifications. Significant associations remain concentrated in

Table 12
Random-effects panel probit models with all independent variables lagged by one year.

	Host pre- COVID-19	Host 2021-2023	Source pre-COVID-19	Source 2021-2023
L.dPGDP	0.000213525	**0.000306732***	**0.000106992*****	(-) 0.000231461
	(0.000135003)	(0.000174589)	(0.000024105)	(0.000275050)
L.dUMP	**-0.069873958***	0.030284067		
	(0.037052485)	(0.149761878)		
L.dCLC	-0.068505707	0.974480150*	-0.274443924	-1.023070399
	(0.138761049)	(0.538683944)	(0.258193475)	(1.342537602)
L.EDA	0.169937901	**0.787195811****	0.126666853	-0.285832985
	(0.108627402)	(0.333065914)	(0.223258588)	(0.254166296)
L.CVD		0.000002959		-0.000010566
		(0.000004623)		(0.000016653)
L.UMP			-0.003023250	-0.030504000
			(0.026239664)	(0.042495399)
_cons	0.638102420	-5.990962774*	-3.615255041**	-0.644354430
	(1.287067651)	(3.236494433)	(1.787824909)	(4.129880219)
Observations	450	75	450	75

Note: Standard errors are included in parenthesis. Based on the stationarity results PGDP and CLC enter all models in first differences. UMP enters the host country models in first differences and the source country model in the levels. EDA and CVD retain in levels. Applying first differences reduces the usable immediate post-pandemic period from 2021 to 2023.
The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.
Source: Authors' composition.

the host-country model during 2021-2023, particularly, for economic growth, climate change, and educational attainment. Conversely, none of the lagged explanatory variables is statistically significant for source countries during the same period. These findings improve the temporal ordering of selected host-country relationships but do not establish causal effects, while the source-country results remain constrained by the limited post-pandemic sample.

4.9. Performance of the models

Receiver Operating Characteristics (ROC) curves are reported in the S5 appendix to assess the discriminatory performance of the binary models. The AUC values for the host country models are 0.6849 before COVID-19 and 0.9454 immediately after COVID-19 indicating moderate and strong discrimination respectively. In contrast, the source-country area-under-the-curve values are 0.4940 before COVID-19 and 0.5846 after COVID-19. The pre-COVID-19 source country value is approximately equivalent to random classification while the post COVID-19 value indicates only weak discrimination. Accordingly, conclusions from the source country probit model should be interpreted cautiously. The weak performance may reflect omitted institutional policy and migration network factors, limited variation in the binary outcome and the short post COVID-19 sample.

5. Discussion

The following sections analyse the panel probit regression results for host and source countries, during the pre-COVID-19 and after COVID-19 periods. The Table 13 summarises the expected signs, observed signs and marginal effect percentages from the models.

5.1. Host countries

Prior to the pandemic, economic growth is the only statistically significant predictor of positive PNM, whereas post-pandemic COVID-19 cases and educational attainment also become significant predictors.

Economic growth and increases in ΔPGDP have increased the probability of positive PNM both pre and post-COVID-19 conditions. This concept aligns with the hypothesised outcome based on neo-classical migration theories [6] which states that increased wage differentials drive migratory motives. Additionally, ΔPGDP acts as an indicator to identify countries that guarantee growth for migrants and better economic stability [31]. This is also stated in previous literature based on OECD and EU countries [2,32]. Moreover, this indicates that migrants will have the ability to access a better standard of living along with improved opportunities.

When it comes to the host countries after COVID-19, despite trials of lockdowns and border closures, these countries experienced faster economic recoveries in comparison to source countries, therefore remaining

Table 13
Summary of hypothesis versus results.

Variable	Host Expected		Host Observed		Source Expected		Source Observed		Supported/ Not Supported/ Inconclusive
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
PGDP	(+)	(+)	**(+) 0.001***	(+) **0.002*****	(+)	(+)	**(+) 0.002***	(-) 0.003	Support
UMP	(-)	(-)	(+) 0.031	(+) 1.611	(-)	(-)	(-) 0.011	(-) 0.200	Inconclusive
CVD	-	(-)	-	(+) **0.00006***	-	(-)	-	(-) 0.00004	Inconclusive
CLC	(-)	(-)	(+) 0.151	(+) 0.731	(-)	(-)	(+) 1.309	(-) 1.118	Not supported
EDA	(+)	(+)	(+) 1.414	(+) **2.257***	(+)	(+)	(+) 1.576	(-) 1.324	Supported

Note: The significance levels of 1%, 5%, and 10% are denoted by ***, **, and *, respectively.
Source: Authors' composition.

an attractive destination to migrants. However, in in the initial stages of the pandemic halted the movement of people and was associated with a temporary surge of return migration of immigrants back to their source countries [3]. This could be due to the immediate economic shocks absorbed by host countries due to lockdowns and physical market closures [17,33,1]. This stunted PGDP, which reduced the number of immigrants looking to migrate to these host countries. However, these effects are still minimal compared to other variables and the fast recovery of host economies contribute to a higher marginal effect of ΔPGDP despite post-pandemic adversities.

Furthermore, post pandemic, the variable CVD is also significant predictor of positive PNM, with a very slight marginal effect of 0.00006%. Additionally, the variable signifies a positive relationship with positive PNM as opposed to the hypothesised negative relationship. Despite the initial outpour of migrants due spill effects of the pandemic, post 2021 [34], migrant numbers to host countries have steadily increased with many family and labour migrations in 2023.

Finally, considering the socio-economic factor of EDA, by hypothesis 4, our results show a statistically significant positive relationship between EDA and the probability of positive PNM, with education attainment being the highest predictor. This result can be supported by previous literature based on OECD countries [10] and demonstrates resilience of host countries against economic turmoil despite the closure of and change in educational systems during COVID-19 in these host countries.. Higher EDA could imply better educational infrastructure, which would be an attractive pull factor. This would appeal to many migrants, especially skilled labourers who look for better opportunities post-pandemic. For example, among the host countries, the USA, United Kingdom, Canada, Switzerland, Australia, and Sweden belongs can be deemed to be regarded as the top ten best countries for education [35]. Moreover, due to the rise in advancements in the countries, migrants are assured that they can grow with better skills and qualifications if they migrate to these countries.

5.2. Source countries pre and post-COVID-19

A similar relationship to host countries could be observed for ΔPGDP. The marginal effects show that a one per cent increase in ΔPGDP can be associated with the likelihood of PNM being positive to increase by 0.002%. These findings reinforce previous literature that states a positive relationship between migration and economic growth [36,4]. Whilst these results are significant, the marginal effects of ΔPGDP are minimal. Nevertheless, this finding aligns with neoclassical theories, which indicate that the motivation for migration decreases with the decrease in wage or income differentials between host and source countries.

Alternatively, an increase in ΔPGDP may not always indicate that people will remain in their respective source countries. This can be due to other differences that lies between host and source countries. Majority of the host countries are known to offer better basic needs. Mainly needs such as healthcare, education, employment opportunities, and political stability. Therefore, an increase in ΔPGDP can be a push factor that is helpful to gain the funds needed to migrate into a host country.

Further, similar to host countries before the COVID-19 pandemic, ΔPGDP is the only variable that remained a significant influencer of positive PNM. Whereas the rest of the variables such as UMP, ΔCLC, and EDA acts as insignificant influencers of PNM and this makes it difficult to draw definitive conclusions about its impact on migration decisions for this period. Moreover, when it comes to post-COVID-19, all the variables considered including CVD is insignificant.

5.3. Comparative discussion of host and source countries

The results demonstrate an important asymmetry between host and source migration systems. Before COVID-19, economic growth is positively associated with the likelihood of positive PNM in both groups, consistent with neoclassical migration theory. Nevertheless, the mechanism may differ. In host countries, stronger economic performance can operate as a pull factor through employment opportunities and higher expected returns. In source countries, economic improvement may reduce financial constraints and enable prospective migrants to finance international movement, meaning that growth does not necessarily eliminate emigration incentives. Moreover, the developmental consequences of economic growth depend on how additional resources are governed and distributed. Evidence from South Asia shows that the benefits of resource-based economic activity vary according to development level and institutional capacity [8]. Consequently, rising PGDP alone may not reduce emigration when growth does not generate inclusive employment, public services, or environmental security. Thus, an identical positive coefficient need not represent an identical migration mechanism.

The post-COVID-19 estimates show a clearer concentration of statistically significant relationships in host countries. Economic growth and educational attainment are positively associated with positive PNM, and these relationships are partly supported by the lagged-variable specification. This pattern may reflect the faster reopening of host-country labour markets, renewed demand for skilled workers, international student mobility and migration pathways linked to labour shortages. The positive COVID-19 coefficient in the contemporaneous host model should not be interpreted as evidence that infections attracted migrants. Rather, cumulative case levels may coincide with high-income destinations that experienced substantial infections but also reopened labour and education channels relatively rapidly.

In contrast, none of the examined variables is statistically significant in the source-country binary model during 2020–2023 or in the lagged model during 2021–2023. This does not necessarily demonstrate that economic, social and environmental factors ceased to influence migration. The heterogeneous climate results are consistent with evidence that climate vulnerability depends on baseline development conditions, adaptive capacity, infrastructure, and access to resources [37]. Therefore, a similar temperature change may create different migration pressures across host and source countries. The insignificant findings may reflect heterogeneous recovery trajectories, mobility restrictions, return migration, remittance disruptions, visa policies, political instability and migrant-network effects that are not included in the model. They may also reflect the short post-pandemic period, limited variation in migration status and weak discriminatory performance of the source-country models. Therefore, the source-country findings are better interpreted as insufficient evidence of stable short-term relationships than as proof that the migration determinants became unimportant.

Taken together, the findings support a differentiated rather than uniform understanding of migration transitions. More broadly, recent sustainability research indicates that environmental relationships vary according to national development pathways, infrastructure, and resilience conditions (R [38].). The contrasting host- and source-country results in the present study are therefore consistent with the view that environmental pressures operate through context-specific economic and institutional mechanisms. Host-country migration status appears more responsive to economic recovery and human-capital conditions, whereas source-country migration balances may depend more heavily on institutional, political, network and destination-country conditions. This asymmetry extends push–pull theory by showing that the same global disruption can alter migration mechanisms differently at the receiving and sending ends of the migration system.

6. Limitations

First, the analysis is restricted to the top 25 host and top 25 source countries identified using average per capita net migration and data availability. The sample therefore represents countries with pronounced host or source migration profiles rather than the global population of countries. Accordingly, the findings should not be generalised to all

countries, smaller migration systems, or bilateral origin-destination migration corridors. Second, the main binary measure captures whether PNM is positive but does not retain the full magnitude of migration balances. Although continuous-PNM models are reported as a robustness check, differences between the binary and continuous findings demonstrate some sensitivity to outcome measurement. Third, the random-effects probit model assumes strict exogeneity and independence between country-specific effects and the explanatory variables. The lagged-variable models improve temporal ordering but do not eliminate endogeneity arising from omitted policy, institutional, political or migration-network factors. Consequently, the estimates should be interpreted as associations rather than causal effects.

Fourth, the 2020–2023 period provides only a short window for examining pandemic and immediate recovery patterns. Differencing and lagging further reduce the effective post-pandemic period to 2021–2023 in the robustness models. The limited sample lowers statistical power and may contribute to Type II errors, particularly in source countries. Fifth, the source-country probit models demonstrate weak discriminatory performance, indicating that the included variables do not fully capture the determinants of source-country migration status. Finally, each conceptual dimension is represented by one internationally comparable indicator. Future research should employ longer post-pandemic periods, bilateral origin–destination migration data, separate immigration and emigration flows, alternative climate indicators, and measures of visa policy, political stability, institutional quality, migrant networks and remittance dependence. Dynamic, correlated-random-effects and instrumental-variable approaches may also provide stronger treatment of unobserved heterogeneity and endogeneity.

7. Policy recommendations

The following policy recommendations are informed primarily by statistically supported findings, while recommendations related to statistically insignificant post-COVID-19 estimates are presented cautiously as tentative and literature-informed considerations. Given the short immediate post-pandemic period and sensitivity across alternative specifications, the recommendations should not be interpreted as causal policy prescriptions.

7.1. Policy recommendations for host countries

In the host-country model, economic growth, educational attainment, and COVID-19-related conditions are statistically associated with the likelihood of positive PNM during the immediate post-pandemic period. Given the short estimation window and sensitivity across robustness specifications, these findings should be interpreted as indicative rather than definitive.

Accordingly, as a tentative policy consideration, host countries may focus on sustaining and improving the quality of educational systems. Ministries of higher education and research (for sustained funding of universities and research institutions), alongside the immigration and labour ministries (for policy implementation and labour market needs assessment) in these countries can implement specific post-study work visas programs and permanent residency options for graduates in high-demand fields.

Further, host countries should focus on developing and maintaining a 'National Economic Stabilisation Fund' or similar fiscal instrument, managed by the central bank or ministry of finance, specifically designed to mitigate initial economic shocks to sustain the perception of consistent economic strength.

The counter intuitive results that show increase in ΔCVD increase the likelihood of positive PNM suggests that host countries remain highly attractive, potentially due to rapid recovery systems that these counties have in place relative to source countries. Therefore, it is recommended to establish a dedicated ‘International Mobility Protocol', overseen by the ministry of health and foreign affairs, that standardises border control, health screening, and economic support for essential workers during future global shocks. This maintains the perception that the host countries are capable of handling crises quickly, thereby upholding its image as a safe destination.

7.2. Policy recommendations for source countries

None of the examined explanatory variables is statistically significant in the source-country post-COVID-19 model. Accordingly, the post-pandemic estimates do not provide a sufficiently robust empirical basis for variable-specific policy prescriptions. The recommendations for source countries should therefore be interpreted as tentative and informed by the broader migration and sustainability literature, descriptive patterns, and the structural vulnerabilities identified in the sample rather than by statistically confirmed post-COVID-19 effects.

Source countries may consider policies that improve the domestic utilisation of human capital, particularly by expanding employment opportunities, entrepreneurship support, and mechanisms that enable return migrants to apply skills acquired abroad. Investment in climate-resilient infrastructure and disaster preparedness may also strengthen resilience in environmentally vulnerable countries. Similarly, economic-development strategies may place greater emphasis on inclusive growth, employment creation, public services, and institutional capacity rather than relying exclusively on increases in per capita GDP. These recommendations are intended as cautious policy considerations and require validation using longer post-pandemic periods and more detailed bilateral migration data.

8. Conclusion

This study examined whether the associations between economic growth, unemployment, climate change, educational attainment, COVID-19 cases and the likelihood of positive per capita net migration differed across host and source countries before and during the immediate aftermath of the COVID-19 disruption. By combining migration push–pull, neoclassical, dual labour market, human capital and environmental perspectives, the study provides a comparative framework for understanding how global shocks may operate differently across receiving and sending migration systems.

The principal panel probit results show that economic growth is positively associated with positive PNM in both host and source countries before COVID-19. During 2020–2023, economic growth, educational attainment and COVID-19 cases are statistically significant in the host-country model, whereas none of the examined variables is statistically significant in the source-country model. The continuous-PNM and lagged-variable analyses provide partial support for these findings but also demonstrate sensitivity to the measurement and timing of the variables. In particular, the lagged specification continues to identify significant host-country relationships for economic growth, climate change and educational attainment during 2021–2023, while no significant lagged associations emerge for source countries.

These results indicate an asymmetry between host and source migration systems but should not be interpreted as evidence of permanent structural change or causal effects. These findings apply specifically to countries with pronounced host and source migration profiles and should not be interpreted as globally representative of all countries or bilateral migration corridors. The short post-pandemic period, weak source-country model performance and possible omitted institutional and policy factors require cautious interpretation. The findings are therefore best regarded as early evidence of short-term migration adjustment. Future studies using longer post-pandemic periods, bilateral migration flows and stronger identification strategies are needed to determine whether these patterns persist.

Statements and declarations

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Data availability

All data generated or analysed during this study are included in this published article and its supplementary information files.

Ethical approval

This study was approved by the Sri Lanka Institute of Information Technology, Sri Lanka (PVC/RI/EC/2025/04).

CRediT authorship contribution statement

Ruwan Jayathilaka: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Shehani Wijayawardena:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis. **Shamen Landersz:** Writing – original draft, Visualization, Software, Methodology, Data curation, Conceptualization. **Yusra Azmi:** Writing – original draft, Validation, Software, Methodology, Data curation. **Lucius Chloe:** Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation. **Pramoda Dissanayake:** Writing – original draft, Validation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.wds.2026.100375.

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