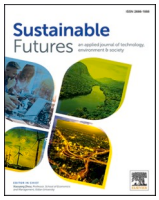
Sustainable Futures 10 (2025) 101485

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures



Poultry consumption and sustainability: Assessing economic, trade, and climatic impacts across diverse income economies

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ARTICLE INFO

Keywords:
Poultry consumption
Gross domestic product
Temperature
Trade openness
Meat types

ABSTRACT

Poultry consumption has increased significantly throughout the world, driven by shifts in economic, trade and dietary factors. This study explores the impact of per capita gross domestic product, trade openness, average surface temperature, beef, pork, sheep, goat, and other meat consumption on poultry consumption in the top 10 countries from each income group. Secondary data for 40 countries were incorporated from Our World in Data, from 2000 to 2021. The Panel regression technique was conducted, which applied Pooled ordinary least squares, fixed effect, and random effect models. The findings indicated that per capita gross domestic product and average surface temperature significantly impact poultry consumption. In contrast, trade openness and sheep and goat consumption significantly negatively impact all 40 countries. In high-income countries, trade openness, average surface temperature, and pork consumption have a positive effect, while other meat consumption negatively impacts poultry consumption. Average surface temperature has shown a notable positive impact, whereas trade openness negatively impacts poultry consumption in upper-middle-income countries. Pork consumption has shown a considerable positive impact in lower-middle and low-income countries.

1. Introduction

Meat consumption has emerged as a growing concern that impacts food security, ecological sustainability, economic growth, and climate change [52]. In recent decades, meat consumption has shown a significant increase in the global context [67]. It has become pretty standard in Western diets and has been widespread and increasing in other parts of the globe [39]. The volume and type of meat consumed differ across nations due to a wide range of factors, including living standards, livestock production, consumer prices, macroeconomic conditions, income levels, urbanisation, cultural preferences, population growth, food availability, climate conditions, dietary shifts, and consumer concerns about animal welfare [12,13,44]. Consequently, meat consumption can be determined by several factors.

From a broader perspective, meat consumption includes numerous types of pork, beef, poultry, seafood, goat, sheep, camel, etc. The most popular globally are poultry, pork and beef, respectively [57]. The average daily meat intake per capita in developed countries ranges from 225 g to 330 g, while in the least developed countries, it remains around 40 g, where poultry and beef act as prominent sources. However, an increase of 10 g per capita per day can be seen in the latter section from 2001 to 2011 [35]. Poultry Consumption (PC) has significantly increased worldwide from 2010 to 2021, with the highest growth seen in Micronesia and South Africa [18]. As of 2023, the United States leads with over 50 kg per year per capita poultry consumption, followed by Israel, Australia, and the United Kingdom. Countries like Saudi Arabia, Malaysia, and Brazil also report high poultry consumption, followed by South Africa, Mexico, and France, probably due to rising incomes, government initiatives, and diversity of culinary traditions [14]. The consumption of white meat type poultry has significantly increased compared to other types, as it is cheaper than most red meat types and allows consumers to gain animal proteins at a lower cost, often considered healthier, and less likely to be affected by religious restrictions than other meat types [44]. However, it can be noted that poultry still has a prominent place among meats.

Fig. 1 illustrates the variation in each meat type measured in kilograms per year per capita from 2000 to 2021 globally. Beef, pork, sheep and goat, and other meats, display a nearly constant behaviour. In

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https://doi.org/10.1016/j.sftr.2025.101485
Received 1 June 2025; Received in revised form 15 August 2025; Accepted 26 October 2025
Available online 31 October 2025

contrast, Beef Consumption (BC) and pork hover around 1500, while sheep and goat consumption (SGC) and other meat consumption (OMC) remain below 500. Notably, poultry consumption reached approximately 2700 kg per year per capita by 2021, up from 1500, representing a significant increase.

Thus, in the current study, the authors use Panel data from 40 countries sampled from 127 countries, specifically focusing on poultry, the dominant meat category. They analyse the impact of factors such as Per Capita Gross Domestic Product (PGDP), Trade Openness (TO), Average Surface Temperature (TEMP) and the consumption of other specific meat categories within a global context, comparing them across different income levels. Sampling was based on the highest coefficient of the linear trend line drawn on the poultry consumption line graphs, which is presented in Appendix 1. The income levels are based on the World Bank classification. Countries are categorised into four groups, according to the Gross National Income (GNI) per capita as high, upper middle, lower middle and low-income. The illustration in Fig. 2 represents the 40 countries as a percentage of poultry consumption. High-income countries represented the highest consumption rate, which is 47.4 %. Considering both upper middle and lower middle countries poultry consumption had not shown a significant increase. However, when comparing all four income groups, low-income countries have shown a significant decrease in poultry consumption.

Global poultry consumption is influenced by various interrelated factors, both directly and indirectly [15]. Feed prices, trade policies, tariffs, government regulations, subsidies, consumer demand, cost of production, fluctuations in currency exchange rates, disease outbreaks such as avian influenza, climate change and environmental factors, market competition, and technological advancements together create a complex and dynamic impact on poultry consumption patterns worldwide. As poultry birds are considered homeothermic animals, ambient temperatures are essential for survival. Thus, the temperature of a country can significantly influence poultry production and poultry consumption [47] . Additionally, it is noted that, as beef and pork prices rise, consumers increasingly turn to chicken as a cost-effective alternative [21] . Hence, the demand for chicken increases with the price rise of other options.

Per capita GDP is commonly used to measure a nation's economic performance. It reflects a country's income level and overall market dynamics and is a unit of measure for comparing economic levels across countries. The current study incorporates per capita GDP as an independent variable. The extent to which a country engages in international trade affects market accessibility and meat prices. These aspects are captured via the trade openness index, which significantly impacts meat consumption patterns. Environmental and climatic conditions have also been identified as significant determinants of food production & availability. However, there is a lack of evidence to determine whether a climate change indicator, such as surface temperature, directly impacts meat consumption by significantly influencing livestock production. Food availability is evident with the current global warming and climate change. Therefore, it is appropriate to highlight the impact of temperature on poultry consumption patterns globally. Additionally, to capture the effects of choices available to consumers, the authors included beef consumption, pork consumption, sheep and goat consumption, and other meat consumption as independent variables.

The current study meaningfully contributes to the existing literature by providing empirical evidence on the impact of economic, trade, and environmental factors on poultry consumption. The results will interest economists, agricultural policymakers, ecological analysts, poultry industry stakeholders, and researchers keen to analyse demand trends and subsequent actions to inform decisions. The critical gaps addressed in the existing literature in this study have hitherto received relatively little attention to date.

First, despite the growing global concerns regarding climate change, most existing research has primarily focused on its impact on production, livestock yields, and the efficiency of supply chains, with little investigation into the relationship between average surface temperature and poultry consumption. The relationship between average surface temperature and meat consumption is important, as most studies have focused on supply-side outcomes, focusing heavily on red meat, rather than poultry meat. However, the extent to which average surface temperature affects chicken consumption habits and preferences is well addressed, and this study fills that gap by directly examining this climate factor. Through this study, it helps to understand how temperature

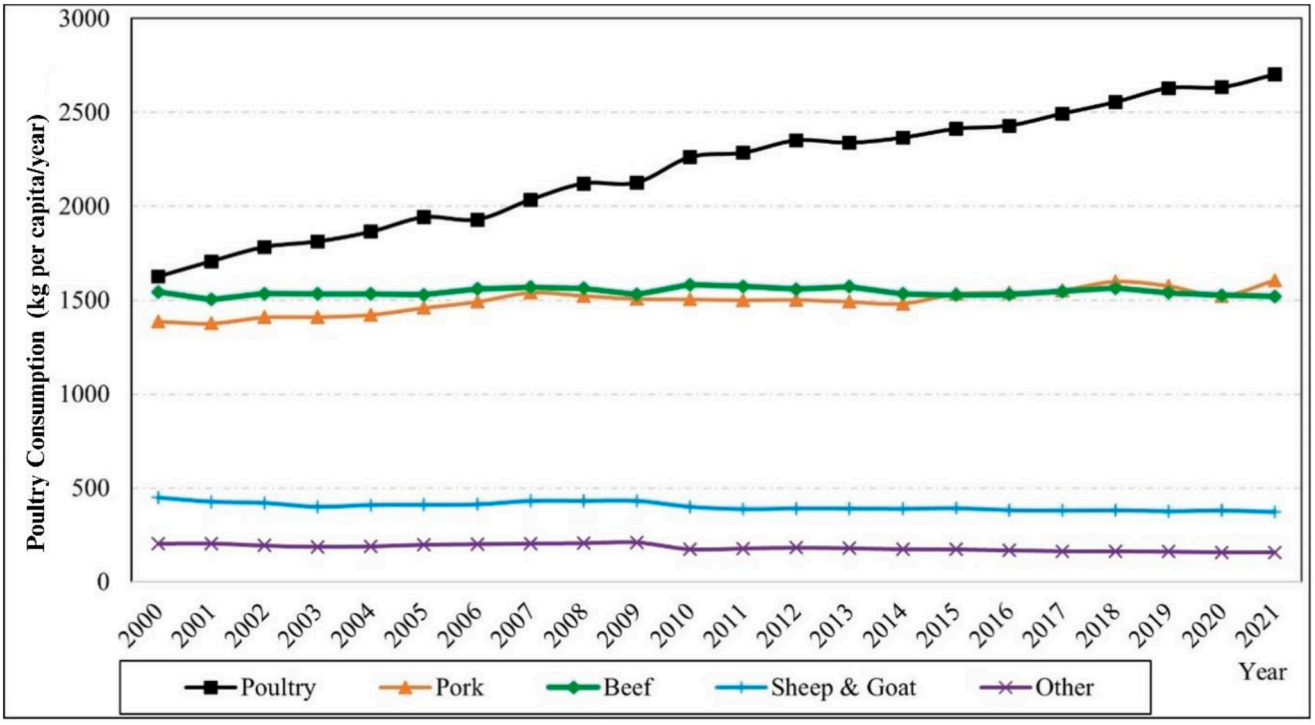

Fig. 1. Type-wise sum of meat consumption from 2000–2021. Source: Authors' illustration based on data.

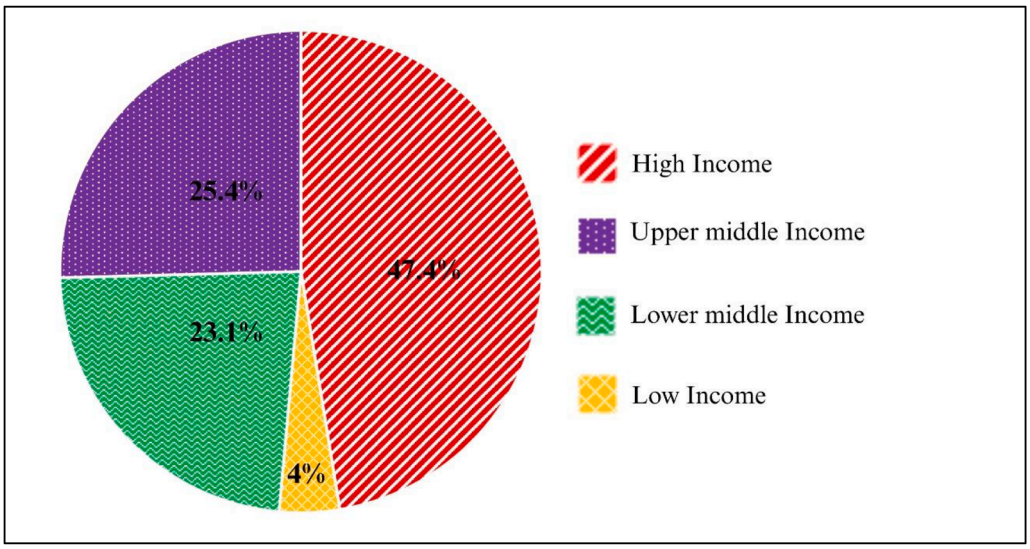

Fig. 2. Income based distribution of Poultry consumption. Source: Authors' illustration based on data.

shapes consumer choices, especially benefiting climate policymakers and environmental ministries in predicting shifts in dietary preferences.

Second, per capita GDP, trade openness, and average surface temperature have been previously investigated and typically analysed in isolation. This current research contributes to the literature by providing a more comprehensive and integrated overview of the impact of the collective economic and environmental factors on poultry consumption, identifying interaction effects and potential confounding relationships, and facilitating a thorough understanding of how these factors collectively impact consumers. By integrating these variables together, it helps to reflect the real-world complexity, such as a person's choice or the decision to consume poultry might not be only impacted through income but also might be due to price changes that happen due to trade policies, climatic changes.

Third, the impact of other meats on poultry consumption has been explored less thoroughly. To determine how other meats affect chicken consumption, this study examines substitution effects and portrays consumer behaviour more accurately. Moreover, much of the existing research has been geographically limited, typically at the country or regional level. In contrast, this study adopts a global perspective to draw conclusions that are both broad in scope and contextually relevant, considering the economic and environmental factors that influence chicken consumption across the various income levels and the impact of meat substitutes. This stratification helps to capture the heterogeneity in consumption patterns, which uncovers the patterns that might remain hidden in the regional context. It ensures these findings will be applicable broadly, for both global and region-specific policy interventions.

This study offers a novel contribution to the literature on poultry consumption by conducting one of the most comprehensive global analyses to date. Unlike previous research, which has typically focused on limited geographic regions or a narrow set of variables, this study examines the impact of a wide range of economic, environmental, and dietary factors that includes factors like GDP, trade openness, average surface temperature, and various categories of meat consumption on poultry consumption across 127 countries over a 22 year period (2000–2021). Furthermore, by classifying our analysis based on income levels and selecting a representative sample of 40 countries with the most significant consumption trends, the study provides insights into how poultry consumption differs across income groups. Considering panel regression, this study also enables a robust and multidimensional understanding of global poultry consumption patterns.

The subsequent sections of this study include a critical literature review, data, and methodology, followed by results and discussion, conclusions, references, and, finally, supplementary materials containing further information about the study.

2. Literature review

The literature comprehensively explores the factors impacting poultry consumption across countries and income levels, specifically focusing on per capita GDP, trade openness, average surface temperature, and other meat types. By integrating evidence from past literature, this review aims to identify shifts in poultry consumption patterns across different socio-economic and geographic contexts.

2.1. Poultry meat consumption

The global consumption of meat has been a widely studied research topic due to its significance and key role in global dietary patterns, where meat is considered an essential component in the human diet [1]. Poultry was considered the fastest-growing meat sector and expected to go past pork in a global review, while poultry acted as a daily protein requirement for humans [4,50]. The poultry products, especially eggs and chicken, were the most preferred sources of non-vegetarian food, mostly due to taste, affordability and ease of preparation [2]. However, the growing demand for poultry raises critical concerns about the environmental impacts of meeting this demand. Individuals with higher socio-economic status and those who reside in urban areas tend to eat healthier with more variety, including meat such as poultry [33]. However, this relationship may be more complex in the case of middle-income countries, where socio-economic consumers with high economic status might adopt unhealthy dietary habits. Analysing poultry consumption patterns, meat is the most preferred, and pork is the least preferred in India [25,61]. The highest willingness and the most preferred meat type from chicken was identified as broilers, mostly due to accessibility and affordability [27,61]. The educational levels did not significantly impact the quantity of poultry consumed, which raises a question about whether several studies, for instance, the per capita poultry consumption, are affected by the levels of education through awareness [8]. In conclusion, the above results have been examined country by country, without a global aspect. However, this study focuses on a worldwide review of how meat types and the main independent variables, per capita GDP, trade openness, and average surface temperature, impact poultry consumption over time.

Considering the attributes affecting the consumption of poultry, the product appearance was the most important indicator, and poultry

consumption was recognised more favourably than beef or pork [29]. In contrast to these attributes, accessibility or ease of purchasing poultry was another factor, as 99.9 % of the respondents in Pakistan had easy access to poultry products, such as thigh and chest [23]. Some respondents also proved that poultry is an essential source of protein in human diets. In addition, poultry consumption was directed by affordability, and poultry has replaced beef and pork in the Polish market [60]. The production and consumption of chicken meat from 1980 to 1998 had increased, which caused the chicken meat prices to decrease, indicating that chicken meat consumption will tend to increase, raising concerns about its potential impact on food security, the public health status and the environment [17,56]. Socio-cultural factors were found to be a primary reason for driving poultry consumption, which could generate risks for public health while causing consumption inequalities among countries [54]. Despite the socioeconomic factors, psychological factors had also shaped the consumption patterns of poultry, such as the effect of buying features, cultural factors, behavioural attitudes, subjective norms and perceived behavioural control, which stimulated consumers' intentions and actual purchase of chicken meat [26].

Nevertheless, there remains a need for empirical research to understand how these factors interact with economic constraints, especially in the case of low-income groups, where affordability or accessibility might override personal or cultural preferences. Moreover, poultry was the main reason for the decline in beef consumption in the European study [32]. From this, the authors concluded that a person's income level influences their preferences for types of meat, determining whether the meat type is considered a luxury or a necessity.

Using linear regression statistical tests, it was found that income was the most effective factor compared to consumption levels and household behaviour [65]. However, a significant shortage of chicken meat consumption among the households of the lowest income group in Turkey, which could benefit from a higher income level. By reviewing these studies, poultry consumption might not have a significant impact whenever income is said to increase or decrease.

Past studies of per capita poultry consumption have only been reviewed country-wise or region-wise. Therefore, the data is limited to those countries or regions where past researchers have identified the primary determinants. In this study, the researchers aim to provide a comprehensive overview of poultry consumption at the global level.

2.2. Poultry consumption and gross domestic product

Income levels or per capita GDP levels have also played a significant role in affecting poultry consumption. Income has been evaluated as an important indicator of demand for poultry, where with a one unit increase in income, there might be a 0.001 kg increase in the demand for poultry [20]. The low price compared to red meat makes it affordable for consumers to purchase poultry [5]. Adding a new perspective to the existing discussion, the per capita poultry consumption has significantly increased more than pork, beef, goat, and other meat consumption in the high-, middle-, and low-income groups [59]. Despite the relationship between income inequality and meat consumption, the results stated that with a 0.1 increase in income inequality of the residents in China, overall meat consumption by 2.53 g/day and poultry consumption by 0.85 g/day are said to increase [30]. This is likely because wealthier residents with higher disposable incomes might consume more meat than lower-income groups. Therefore, this strongly suggests how economic inequality among country residents can impact consumption or dietary patterns.

Poultry was considered a healthier, cost-effective, tastier meat type and less expensive [34]. This indicated that, with income elasticities, the demand and the willingness to consume chicken may vary. Adding to the same, the income elasticities of poultry consumption were estimated [6], and the researchers have analysed that breasts and thighs are considered superior products. In contrast, for carcasses a negative elasticity was observed. This indicates that because the overall consumption of poultry is low-income elastic, it may increase or affect the different national incomes. It concludes that when Brazilian buyers' incomes rise, they are more likely to switch from eating whole carcasses to consuming special parts like thighs and breasts, which have high elasticities. The results also show that although national income will rise, consumption of poultry, particularly carcasses, will not rise much. Moreover, using linear regressions for a global analysis, income significantly impacts the level of demand and annual poultry consumption per capita, showing an upward trend [63]. Poultry consumption was considered the primary driver of increasing total meat consumption compared to beef or lamb in most countries. In contrast, per capita GDP increase was associated with the change in total meat consumption, affecting the consumption trends of poultry consumption.

Most studies have been done at a macro level, considering economic growth and poultry consumption. However, in this study, the per capita income and impact on poultry consumption are more critical because it looks at a micro level. Therefore, this study highlights the gaps in how the per capita GDP will significantly impact poultry consumption when the income of the households either decreases or increases.

2.3. Poultry consumption with trade openness

The pattern of poultry consumption reveals a direct influence of trade openness measures, particularly in developing countries. Consumer exposure to reduced trade barriers reveals a broader range of poultry products that redefine consumer preferences. The evaluation assesses consumer preferences and examines non-tariff regulations alongside their impact on poultry sales via worldwide networks.

The growth of non-tariff measures has caused a significant increase in the global meat trade, thereby increasing poultry consumption [49]. Non-tariff measures have made it easier to conduct poultry trade since they improve product quality, which builds consumer trust in imported products. Implementing these measures creates new barriers that reduce local producers' opportunities to export poultry [16]. However, the extent to which each country depends on its own domestic production or international trade varies based on its economic status. Past researchers have considered the impact of trade policies and restrictions on poultry consumption and have expressed varying ideas.

Probability and non-probability sampling methods were deployed to analyse consumption patterns in Ghana. Chicken was found to be consumed regularly, and chicken meat was the common chicken source [43]. This strongly depicts that it is considered a primary source in the markets; therefore, the availability of meat to consumers in Ghana and worldwide is critical, while ensuring the significance of trade openness in a country.

Furthermore, it was stated that Vietnam imports more poultry than it exports, as elevated local prices made it less competitive in the global market [9]. Nonetheless, people in Vietnam prefer local chicken breeds despite their high cost due to their taste, quality, and cultural importance. The benefits of trade openness for market diversity in poultry products can occasionally create market competition for local producers and alter traditional eating patterns that hinder food security and cultural preferences.

The impact of fewer trade rules and regulations on the trade openness of a country will depend on whether trade increases or decreases. Reduced trade barriers will determine how a country's import competition and supply chain efficiency will increase. Therefore, it might decrease the price of poultry products, making them more affordable for households and leading to higher poultry consumption. This study examines the impact of trade openness on per capita poultry consumption, clarifying the relationship between trade policy, market forces and consumer behaviour.

2.4. Poultry consumption with temperature

The connection between temperature measurements and poultry

consumption demonstrates multiple levels of complexity. Although chicken is considered the most affordable source of protein, due to a wide range of climatic variations, it heavily impacts poultry production, which will ultimately alter consumption patterns because, irrespective of the chickens' age, they cannot endure high temperatures and high humidity [40]. Although there is no specific literature detailing the direct impact of poultry consumption on climate change in a singular study, the literature highlights the indirect effect of food production, environmental impact and consumer behaviour. In this study, the average surface temperature is used as an indicator to measure climate change. This section further investigates these phenomena individually. Most of the past literature revealed that broilers were the most preferred and were specifically bred to grow quickly. They need optimal environmental conditions to achieve their genetic potential; therefore, the consequent temperature changes and altered precipitation patterns might create an unfavourable environment for broilers to grow, impacting how poultry consumption varies from country to country [42]. Moreover, the accessibility of meat consumption is also significantly affected by land, as countries with higher land per capita consume more meat. Large areas of land are required for livestock, crops for animal feed, and grazing [46]. Fundamental ecological factors significantly influence the intake of meat. People in temperate countries may eat more meat than people in Subarctic and Arctic areas, as the temperature zone is more favourable to grain production, and excess grain is required to produce meat.

Optimised management practices should be developed to adapt poultry production under heat stress because rising global poultry consumption is outpacing temperature effects on farming operations. Heat stress has been a critical issue affecting poultry, as increased environmental temperature has created variations in poultry production [7]. Heat stress has also reduced feed intake, while the poultry industry has been negatively affected, reducing the consumption of poultry [55]. The poultry industry has adverse effects on environmental issues like climate change [3]. Therefore, it is necessary to adopt sustainable methods while maintaining poultry production and consumer consumption patterns.

The study aims to identify specific risk factors related to campylobacteriosis, a disease commonly found in chickens that is likely influenced by climate change [48]. The results indicated that the Campylobacter-associated risk factors will increase due to climate change. According to the reviews of this research, there is a significant risk associated with consuming campylobacter-contaminated meat, which will impact consumption; therefore, based on this study, the authors will investigate how temperature may increase or decrease and how it will affect the increase or decrease in poultry consumption.

Overall, the studies illustrate the relationship between food production, consumer awareness, and environmental impact on how patterns of poultry consumption may be affected over time by climate change. In this study, the reduction of poultry consumption as a potential climate strategy ensures that alternative diets satisfy nutritional standards while promoting sustainability, as dietary adjustments impact human health and environmental conditions. This study examines how variations in average surface temperature, whether an increase or a decrease, impact poultry consumption, addressing this aspect in depth.

2.5. Poultry consumption with meat types

Dietary consumption of meat and poultry varies substantially across cultural regions, depending on regional food choices, financial standing, and natural preservation considerations.

Market demand has increased due to lower poultry meat prices, as it contains higher protein and lower fat than traditional red meats [24] . These studies suggest that global consumption of poultry has increased and is considered the most commonly consumed type of meat in the U.S [10]. The reason for the increase in the consumption of poultry over the past decades and why it remains a primary source of protein in human diets is depicted above.

Red meat represents the most significant proportion of meat consumed in the USA, despite the shift towards higher poultry consumption; only 22 % of processed meat was consumed [12]. However, it has been revealed that there is a strong tendency to reduce the consumption of red meat. In contrast, the trend in pork consumption remains less clear, and poultry consumption is anticipated to increase [19]. This clearly shows that other meat consumption significantly impacts poultry consumption.

People worldwide adjust their meat consumption levels because of cultural traditions, economic systems, and environmental constraints. Avian food consumption now surpasses beef consumption in America, with chicken surpassing all other poultry products as the preferred choice [10]. Despite the increase in poultry consumption, additional research needs to analyse how much it directly influences poultry and how such a relationship varies by economic and climatic determinants.

Several social and environmental factors influence the consumption of poultry. Although poultry has been promoted and continues to grow globally in many ways as an efficient and more sustainable substitute for other meats, its consumption trends are linked to economic accessibility, cultural traditions, and market forces. Encouraging responsible poultry consumption is central to addressing these problems and maintaining long-term ecological sustainability.

The remainder of this paper is structured as follows: the next section describes the data and methodology applied, followed by a discussion of the results. Finally, the paper concludes with limitations, future research recommendations, and a conclusion.

3. Data and methodology

3.1. Data

This study deploys secondary data for 40 countries from 2000 to 2021, sourced from Our World in Data. The data file used for the study is given in Appendix 2. Based on the accessibility and the availability of data, the selection of the periods was included in the study. The variables analysed are PC, POC, BC, SGC, OMC, PGDP, TO and TEMP. Consumption of meat types was measured in kilograms per year per capita. Per capita GDP is presented in constant 2021 international dollars. Celsius measures average surface temperature, and trade openness is expressed as a percentage of GDP.

Table 1 represents variables, measurements, and sources.

3.2. Methodology

The static linear model below can be used to measure the impact on poultry consumption across different income groups. This analytical technique allows one to examine the cross-sectional, entity-wise, and time-wise variations in poultry consumption.

$$PC_{it} = \beta_0 + \beta_1 PGDP_{it} + \beta_2 TO_{it} + \beta_3 TEMP_{it} + \beta_4 POC_{it} + \beta_5 BC_{it} + \beta_6 SGC_{it} + \beta_7 OMC_{it} + \varepsilon_{it} \quad (1)$$

Table 1
Data sources and variables.

Variable		Measurement
PC	**Poultry Consumption**	Kg per year per capita
BC	**Beef Consumption**	Kg per year per capita
POC	**Pork Consumption**	Kg per year per capita
SGC	**Sheep and goat Consumption**	Kg per year per capita
OMC	**Other Meat Consumption**	Kg per year per capita
TEMP	**Average Surface Temperature**	Celsius
TO	**Trade Openness**	Percentage of GDP
PGDP	**Per Capita Gross Domestic Product**	Constant 2021 international $

Source: Compiled by authors.

Where 'i' represents the country, 't' represents the year. The intercept β_0 represents the poultry meat consumption. When all independent variables are zero, and coefficients $\beta_1,\ \beta_2,\ \beta_3,\ \beta_4,\ \beta_5,\ \beta_6,\ \beta_7$ shows the impact of the independent variables on PC_{it} while ε_{it} stands for the standard error.

Since the data set changes across time with a country-specific impact, the panel data approach is the most suitable model for data analysis, capturing both individual country trends and broader global patterns over time. The three likely estimations of panel regression were used, namely Pooled Ordinary Least Squares (POLS), Fixed Effects(FE) and Random Effects(RE) models [22]. The fixed effect model assumes that differences between individuals can be accommodated by different intercepts. The random effect model will estimate panel data where interference variables may be interconnected between time and between individuals [69] These three models were used to compare the most applicable model using the F test, the Lagrange Multiplier (LM) and the Hausman tests. The F test determines the overall significance of a model and helps to select the best model using fixed effects and POLS. LM test is used to detect heteroscedasticity, which occurs when the change in errors is not constant, and it is used to select the most appropriate model in-between random effect and POLS, while the Hausman test is performed to choose between random effect and fixed effect [53]. Although dynamic panel models (e.g., Arellano-Bond GMM) and instrumental variable approaches were considered, the study adopted a static panel framework (POLS, FE, RE) for both methodological and conceptual reasons. Our primary objective was to estimate the contemporary association rather than the dynamic adjustment parts. Given that poultry consumption is influenced by slow-moving annual indicators such as Per capita GDP, Trade openness and climatic variables, including lagged dependent variables was not essential for addressing the research question. Moreover, a relatively small number of cross sections in each subgroup (10 countries) and the moderate time dimensions (22 years) could lead to instrumental proliferation and small sample bias in estimations.

With regards to the instrumental variable estimations, we acknowledge potential endogeneity but note the absence of strong, valid and globally comparable instruments, covering all countries in the dataset. Applying weak instruments could compromise consistency and interpretability. Instead, we rely on the inclusion of both time and country fixed effects, tested jointly via F-test as reported in Table 2, to mitigate unobserved heterogeneity and reduce omitted variable bias. This specification is consistent with established empirical practices in global consumption studies and is appropriate for the data structure and the scope of analysis.

STATA analytical software was used to derive the descriptive statistics and analyse data, while visualisations were done from Jupyter Notebook, Ink Space, and Canva. The steps followed by the study in the data analysis are represented by Fig. 3.

The diagram indicates the flow of the overall research through each step. Source: Authors' compilations.

Table 2
Specification test results for 40 countries (2000–2021).

Income Level	Tests		
	F- Test	LM Test	Hausman Test (Sigma more)
	H_0: POLS H_1: FE	H_0: POLS H_1: RE	H_0: RE H_1: FE
All	155.17 ***	5205.73***	15.04**
High-Income	104.23***	1136.69***	6.22
Upper-Middle Income	32.15***	443.78***	22.32***
Lower-Middle Income	0.54	0.00	4.80
Low-Income	1.85*	2.02*	11.65

Source: Authors' illustration. Note: The symbols *, ** and *** represent 10 %, 5 % and 1 % significance level, respectively.

4. Results and discussion

This section extensively describes and discusses the findings of the descriptive and panel regression analyses.

4.1. Descriptive statistics

Appendix 3 demonstrates the summary descriptive statistics for the study variables. For each variable and income group, the tab gives the number of observations, mean, standard deviation, minimum and maximum value. There are 880 observations included for all countries, of which 220 relate to each income group as high, upper-middle, lower-middle, and low-income level countries.

To provide a more thorough presentation of descriptive statistics, thematic maps with bar graphs illustrate the significant changes in poultry consumption and independent variables, considering the mean values for each income group between 2000 and 2021. GDP indicates the variation from country to country across the different income groups, which is highlighted by the colour gradient scale. Each country is labelled with its average surface temperature mean value.

An illustration of selected high-income countries, showing the variation in meat consumption patterns and associated economic and environmental variables, is represented in Fig. 4. Accordingly, the Bahamas, Canada, and Australia have a notably high poultry consumption, while countries such as Norway and Greece have shown low consumption patterns. Consumer tastes and preferences have significantly shaped meat consumption patterns in Australia, where consumers have shifted their diets from beef, lamb and mutton to chicken [64]. This reflects broader global consumption patterns of poultry across high-income countries.

The comparative analysis of selected upper-middle countries by visualising variations in key variables is depicted in Fig. 5. The map shows that Peru and Gabon have a lot of food. A sustainable growth in the consumption of poultry has been shown in Peru, driven by many factors, and the leading indicator is GDP [68]. With people shifting towards healthier diets, chicken has shown an increase in consumption with high source of protein compared to red meat [51]. Clearly, the graph illustrates that Gabon shows relatively high other meat consumption patterns compared to other upper-middle-income countries. This could be due to various reasons, such as the variations in temperature and trade openness.

The lower middle-income countries are illustrated in Fig. 6, showing the changes in poultry consumption patterns alongside the independent variables. The highest poultry consumption is in Samoa, and the lowest is in Sri Lanka. Religious beliefs significantly influence poultry consumption, in contrast to pork and beef consumption in Sri Lanka [1]. However, critically analysing the point that religion and culture play a decisive role, other determinants such as trade openness and food policies also come into play.

Fig. 7represents the variation of key variables in low-income countries. For instance, Ethiopia's per capita meat consumption has been low, as not considered an essential part of their household diets [38]. In contrast, Togo has displayed the highest rate of poultry consumption, compared to other low-income countries.

These line charts below represent the varying consumption patterns of poultry for the 10 countries of each income group from 2000 to 2021.

Fig. 8 illustrates the high-income countries. Throughout the observed period, the Bahamas shows the highest consumption, significantly surpassing the other countries. Australia also displays a notable rise in the consumption rate after mid-2010. In contrast, Canada indicates a steady consumption with slight variations. However, Poland, Iceland, Slovenia and Denmark have shown a decrease in poultry consumption in recent years.

Fig. 9, represents the upper-middle-income countries where significant variations have been illustrated in poultry consumption. However, compared to the year 2000, there is an overall increase in per capita

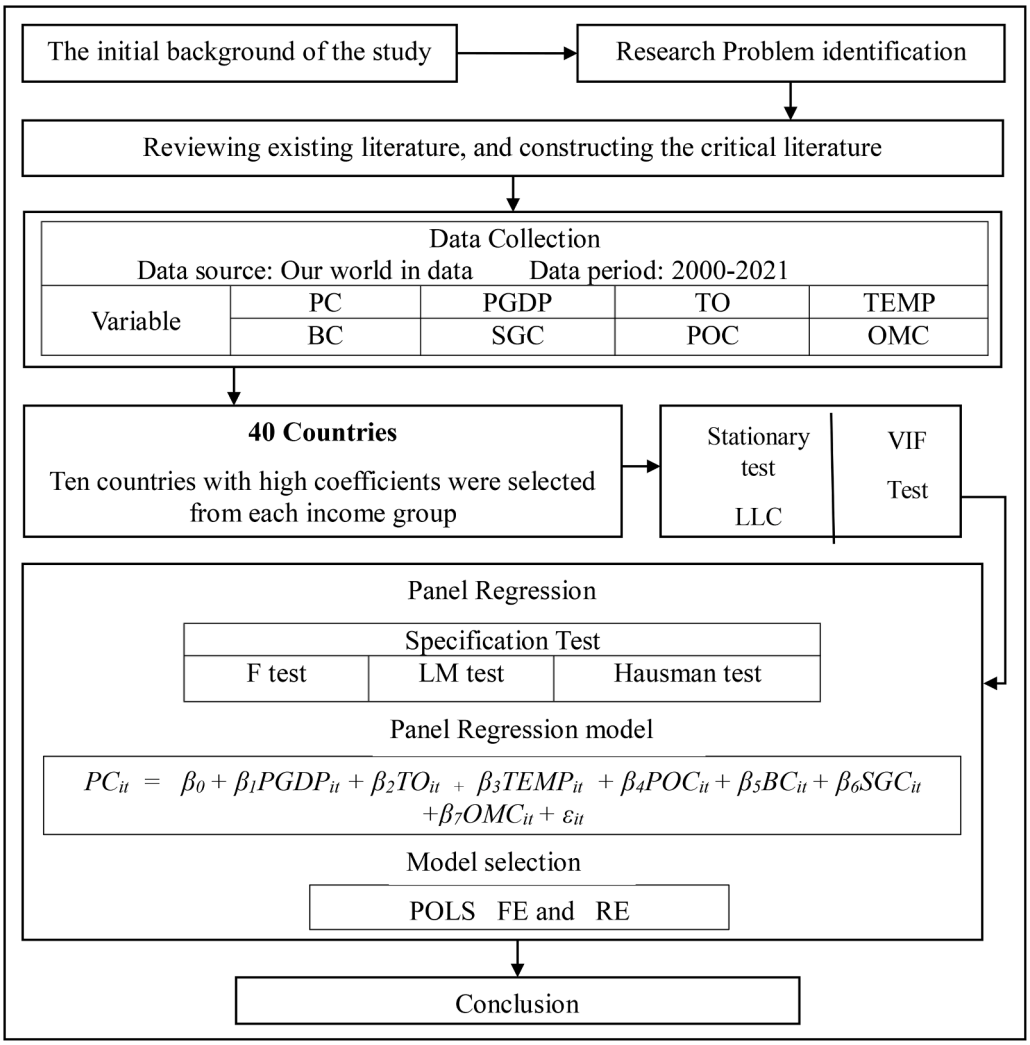

Fig. 3. Workflow diagram.

poultry consumption. In mid-2009, Peru and Fiji significantly increased in per capita poultry consumption. Overall, the graph indicates that the per capita consumption has risen with the demand for poultry. Nevertheless, an increase in income cannot always lead to increased consumption rates, especially in the case of whole carcasses [6]. Consequently, the upward trend cannot always determine how significantly it will influence the quantity of poultry people would consume.

Fig. 10, illustrates the trends of poultry consumption in lower-middle income countries for the period. Samoa had shown a significant increase compared to other lower-middle countries. Cape Verde has decreased per capita poultry consumption in recent years, while India has demonstrated stable per capita poultry consumption. From this graph, we can depict that lower-middle income countries like Sri Lanka, India and Haiti are traditional countries that primarily rely on conventional consumer preferences rather than income levels that impact the consumption and the willingness to purchase or consume poultry.

Fig. 11. depicts that Burkina Faso, Gambia showed considerable increases in per capita poultry consumption in low-income countries. After 2010, Gambia exhibited a consistent and stable increase, whereas Burkina Faso experienced an increase in 2018. Togo, Mozambique had exhibited moderate consumption trends, while Madagascar, Mali, Rwanda, and Ethiopia had not shown a significant increased per capita poultry consumption.

Considering the above graphs, the factors that affect poultry consumption, depend on income levels, consumer attitudes, cultural preferences, climatic factors, and health conditions. When we consider a single household, only one type of meat is consumed at a time; therefore, other meat types also significantly impact the number of poultry consumed. The authors illustrate a comparison in Appendix 4 on how poultry consumption and other meat types have varied over time.

4.2. *Stationarity test*

The Levin-Lin-Chu (LLC) unit root test was undertaken to ascertain whether the variables are stationary. LLC was selected among various unit root tests for this study due to its suitability for assessing unit roots across multiple entities over an extended period. The null and alternative hypotheses were developed to determine stationarity in the panel. The null hypothesis indicates non -stationarity, whereas the alternative hypothesis suggests it is stationary.

Differencing was applied to achieve stationarity, which is denoted by the letter “D” in front of the variable name, categorising across the income groups, at 5 % significance level. The test was continued until the null hypothesis was rejected at the 5 % significance level, verifying stationarity. As some of the variables were found to be non-stationary, the first difference was applied to transform them to stationarity. However, in the instance of per capita GDP, for lower-middle-income countries, although the first difference was used, it was not sufficient to reach stationarity, as it was found to be stable. Therefore, we used log transformation to make per capita GDP stationary, which is denoted by

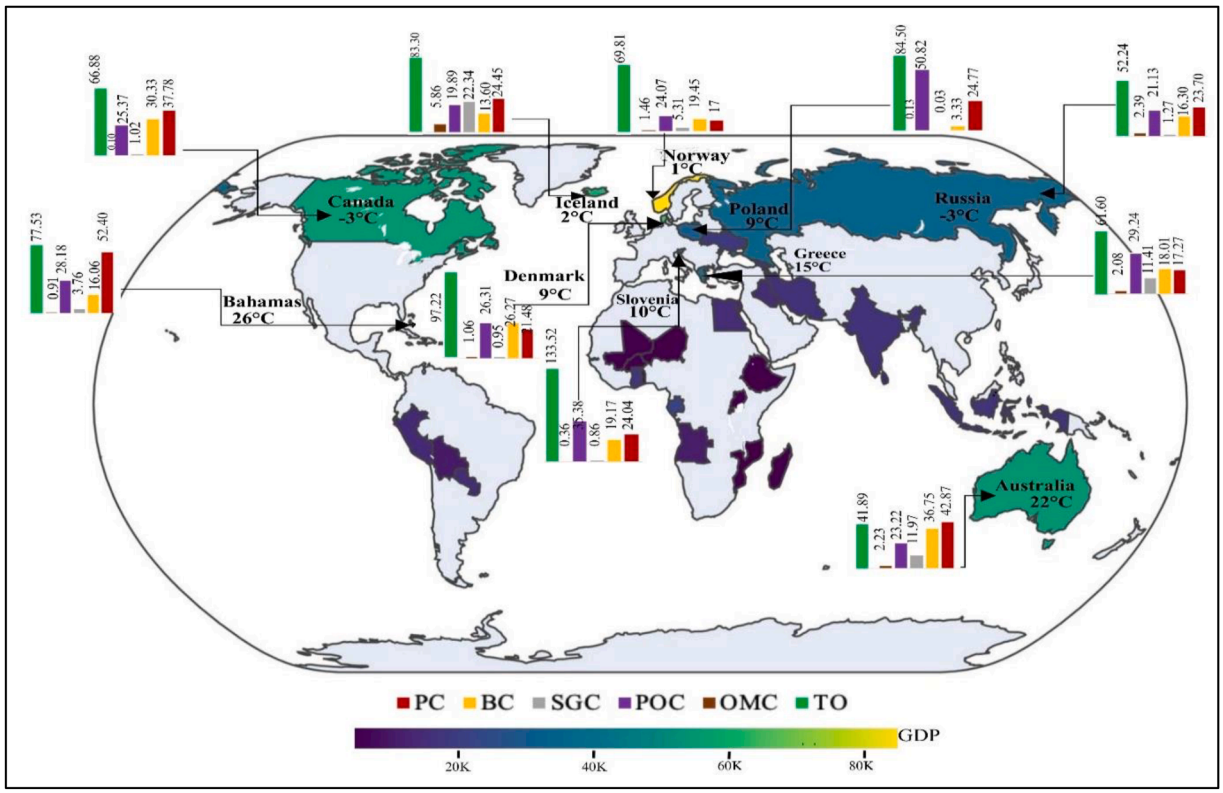

Fig. 4. High income countries illustrating meat consumption, economic indicators, and temperature variation (Developed countries). Source: Authors' illustration based on Our World in Data.

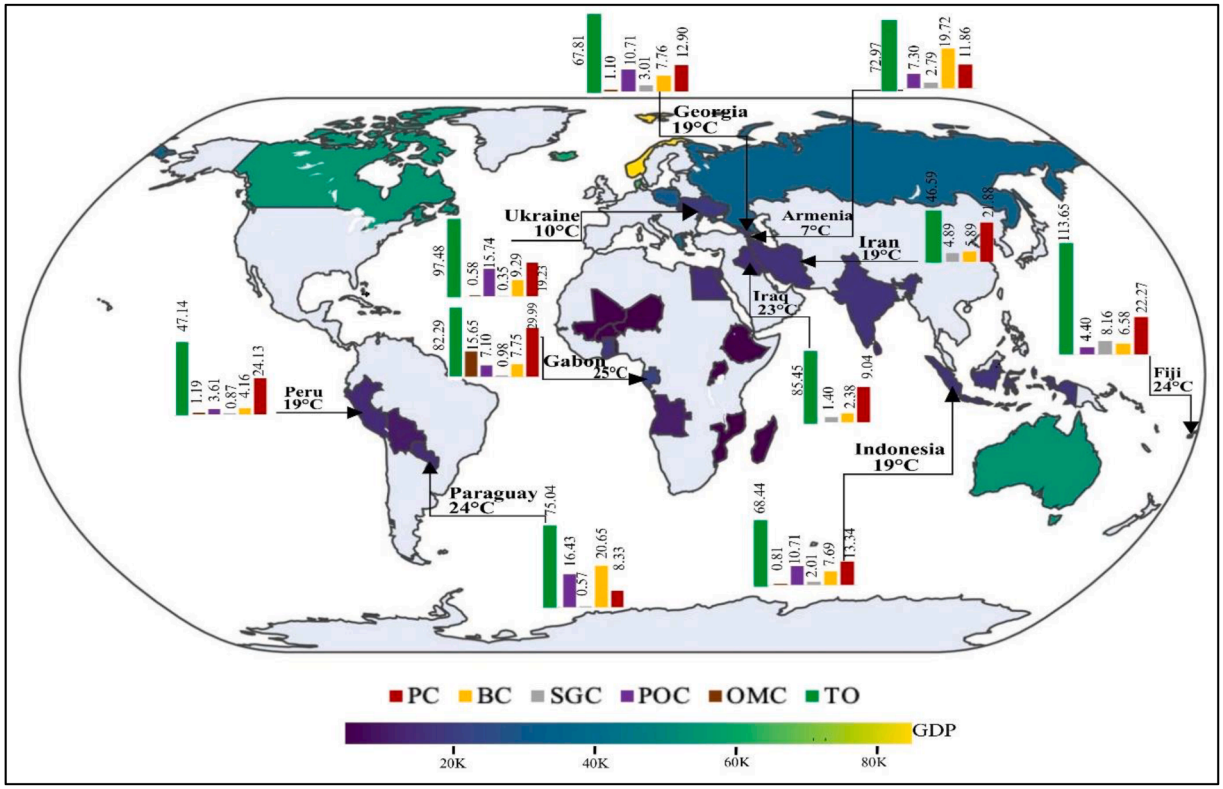

Fig. 5. Upper middle-income countries illustrating meat consumption, economic indicators, and temperature variation (Developing countries). Source: Authors' illustration based on Our World in Data.

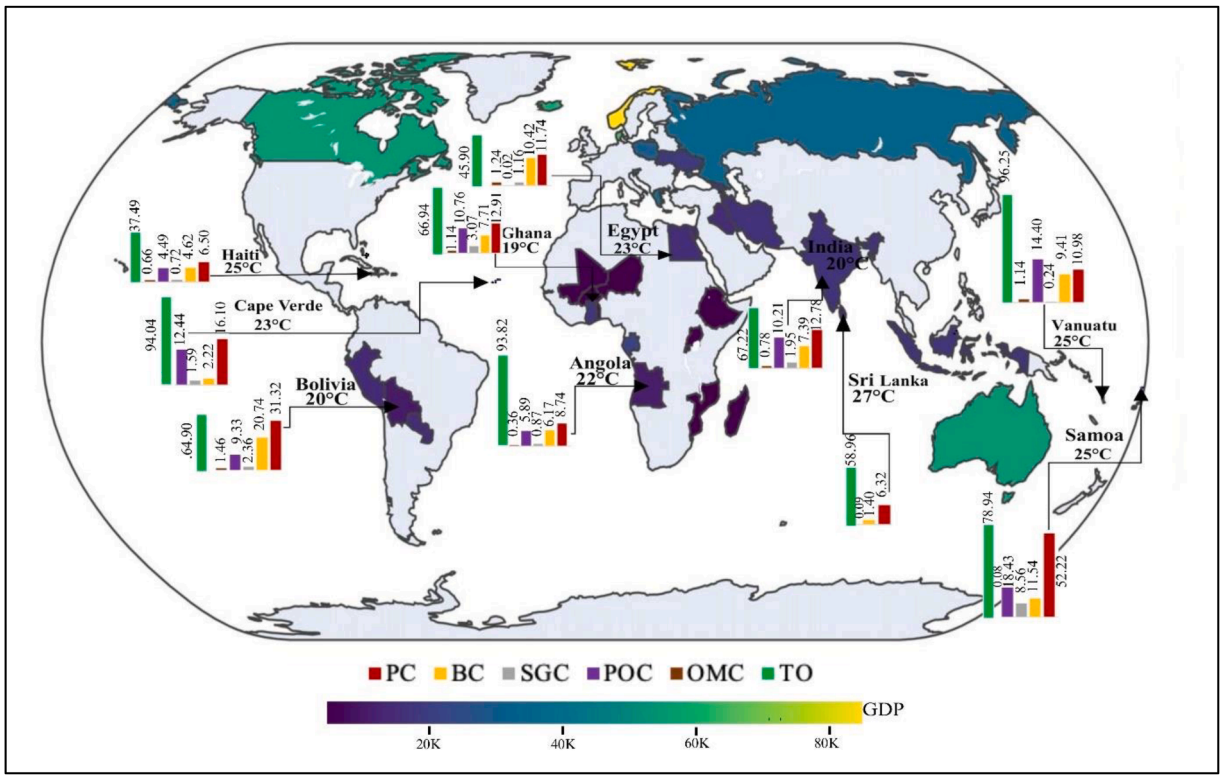

Fig. 6. Lower middle-income countries illustrating meat consumption, economic indicators, and temperature variation (Developing countries). Source: Authors' illustration based on Our World in Data.

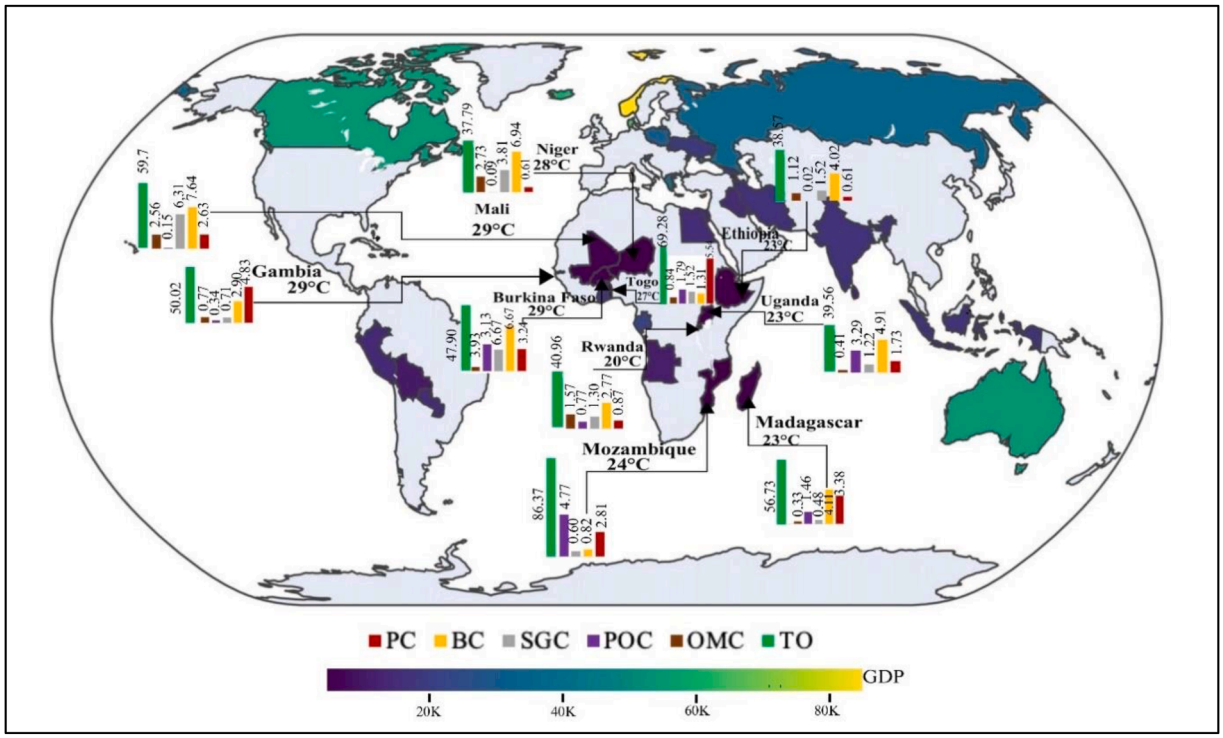

Fig. 7. Low-income countries illustrating meat consumption, economic indicators, and temperature variation (Developing countries). Source: Authors' illustration based on Our World in Data.

the letter "L" in front of the variable name, that assisted in de-emphasising the outliers [36]. Poultry consumption was stationary in all 40 countries, high-income and upper-middle income, while it is non-stationary in low and lower-middle income. Beef consumption has become non-stationary except for upper-middle. Pork consumption has become stationary in all, high and lower-middle countries. Whereas, in

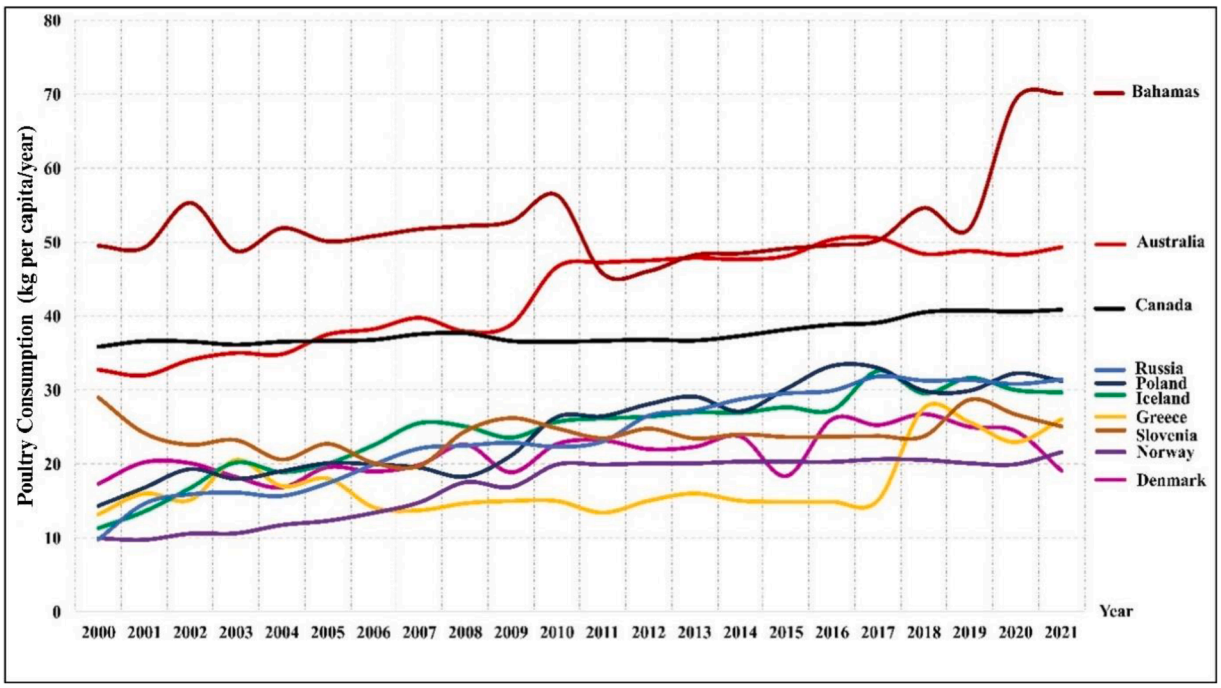

Fig. 8. High income countries illustrating poultry consumption trends (Developed countries). Source: Authors' illustration based on Our World in Data.

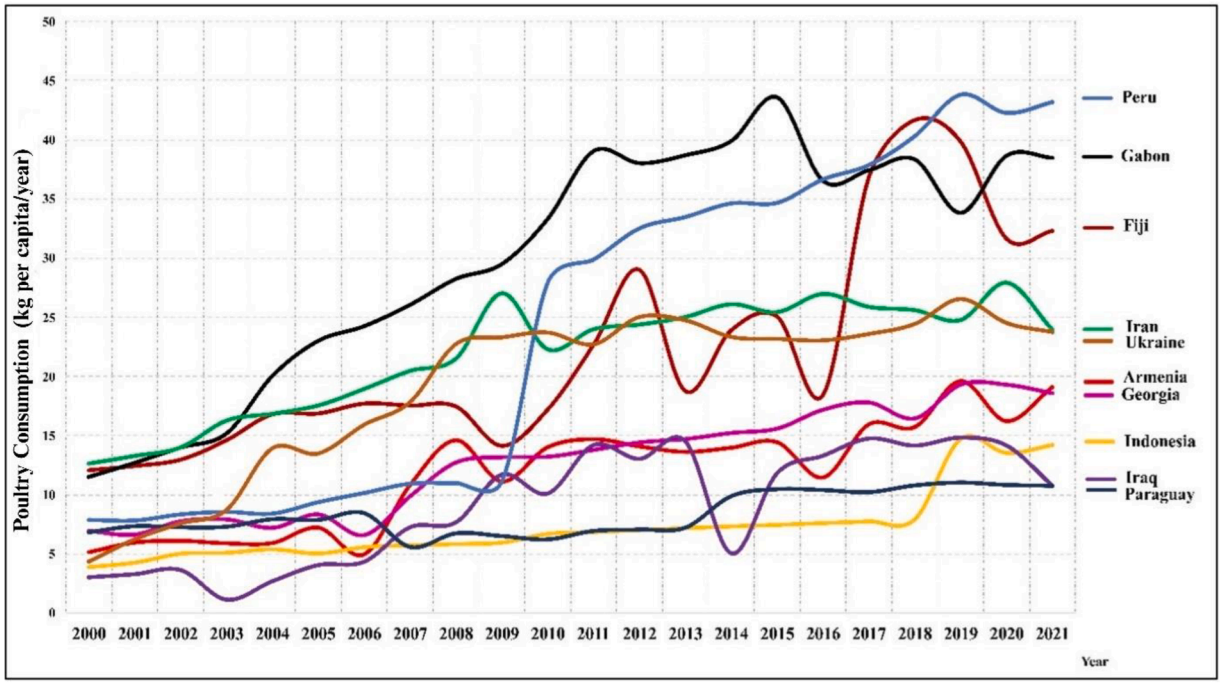

Fig. 9. Upper-middle-income countries illustrating poultry consumption trends (Developing countries). Source: Authors' illustration based on Our World in Data.

low-income countries and upper-middle-income countries, it had remained nonstationary. Sheep and goat consumption in middle-income countries have become stationary; others have remained non-stationary. Other meat consumption has become stationary for all, high, lower-middle income countries. The average surface temperature remains across all income groups. Trade openness is non-stationary only for the low-income group, and is stationary for all the other income groups. Per capita GDP is non-stationary for upper middle, lower middle and low-income countries and is stationary for all and high-income countries. Appendix 5 displays the Stationary test results.

4.3. Multicollinearity test

This test is used to find out if there are any correlations between two or more independent variables. To test this, the Variance Inflation Factor (VIF) was calculated to check multicollinearity among the independent variables. Potential multicollinearity is indicated if the VIF value is greater than 10 [37] The results, provided in Appendix 6, confirmed that multicollinearity was not a significant issue in this study.

The Specification test assesses the most appropriate Regression model for panel data analysis, across all 40 countries, and each income

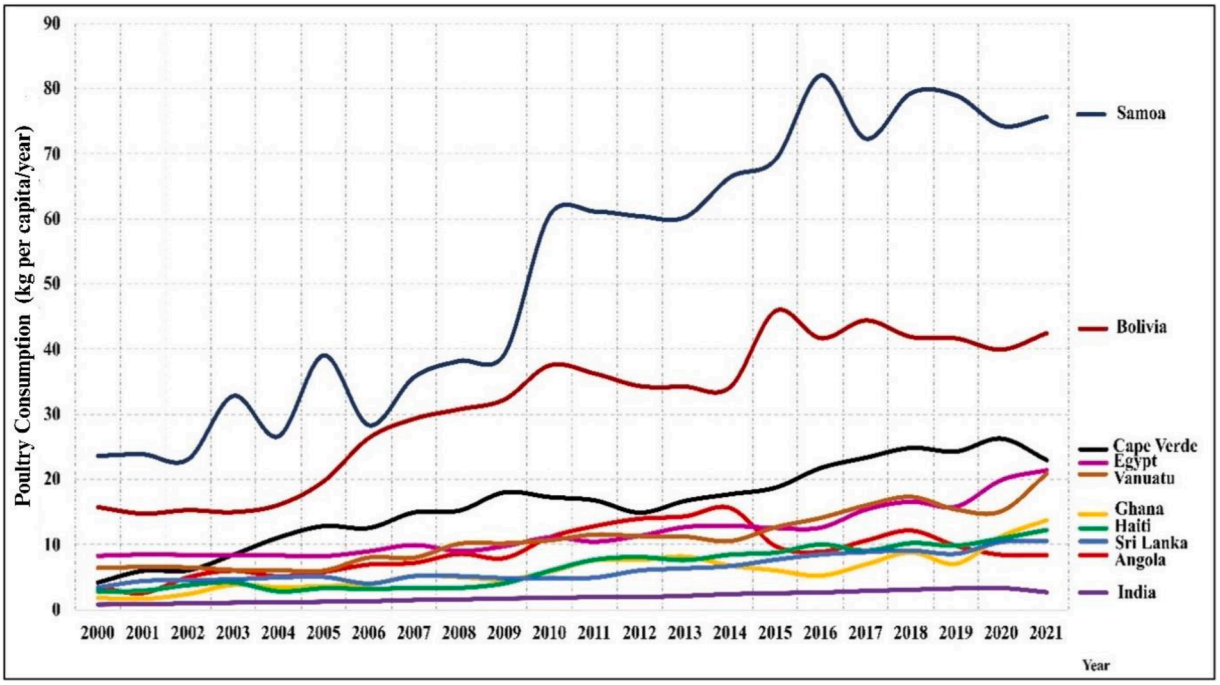

Fig. 10. Lower-middle-income countries illustrating poultry consumption trends (Developing countries). Source: Authors' illustration based on Our World in Data.

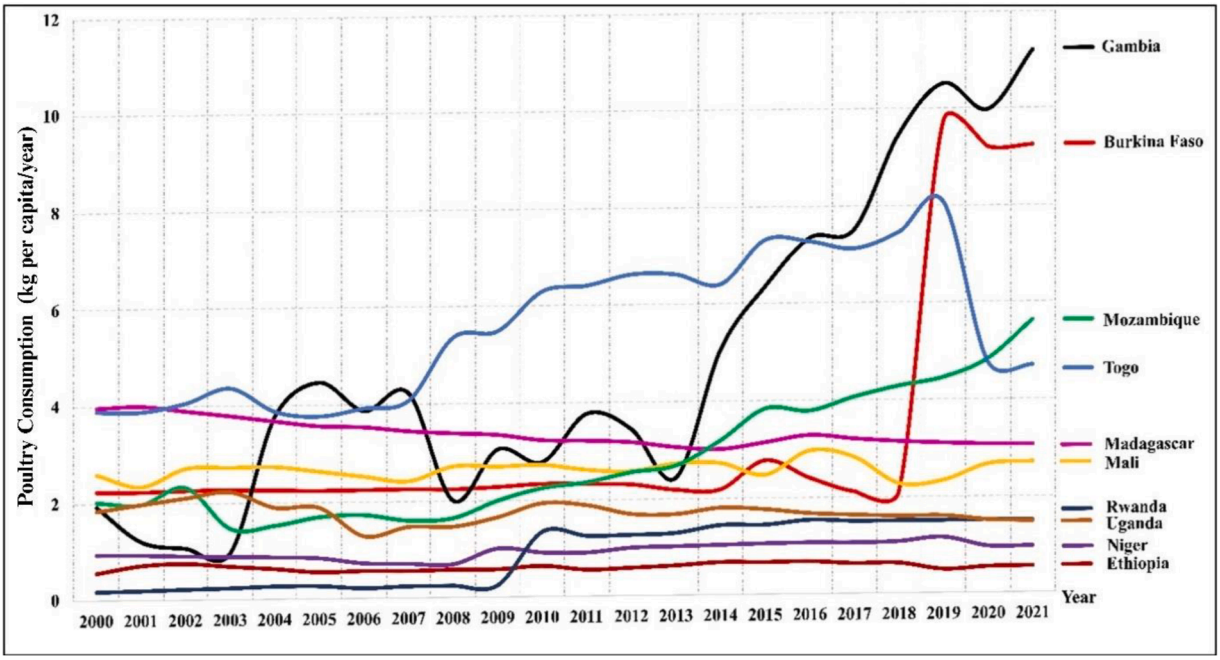

Fig. 11. Low income countries illustrating poultry consumption trends (Developing countries). Source: Authors' illustration based on Our World in Data.

group. The results of the Panel data model specification test is shown in Table 2. The F test is used to reject the null hypothesis of the POLS model among fixed effects. The Breusch-pagan LM test is used to reject the null hypothesis of the POLS regression model. Rejecting the null hypothesis specifies that the POLS model is unsuitable for this study. The probability F and LM test results rejected the POLS regression model for all countries, high-income, and upper-middle income. The results of the probability F test and LM test did not reject the POLS model for lower-middle income countries and low-income countries, which means the POLS approach is suitable for the lower-middle income countries and low-income countries. Because the POLS is not suitable for all 40 countries, high, and upper-middle-income countries, the study presents the Hausman test to find the best model between fixed effect and random effect. Hausman test results indicate that all countries and high-income countries rejected the null hypothesis. Rejecting the null hypothesis indicates the fixed effect model is more suitable than the random effect model. According to the results, fixed effect is the appropriate model for all and high-income countries. Upper-middle-income countries did not reject the null hypothesis. The result indicates the random effect model is more accurate than the fixed effect model. At the same time, POLS is the appropriate model for lower-middle and low-income countries

4.4. Panel regression model analysis

The random and fixed effect models' results are presented in Appendix 7, while Appendix 8 depicts the POLS model results for different income groups. These provide valuable insights into the impact of independent variables on poultry consumption.

Statistical results for all 40 countries in the fixed effect panel data regression indicate that per capita GDP, and average surface temperature have a positive and significant impact on poultry consumption at the 1 % significance level. Trade openness and the consumption of sheep and goats negatively influence poultry consumption at the 1 % significance level. The positive and significant coefficients of per capita GDP and average surface temperature indicate that increases in per capita GDP and average surface temperature can lead to high poultry consumption regardless of the income groups. Conversely, a negative and significant coefficient for sheep and goat consumption indicates that increased consumption of sheep and goat has a greater effect on lessening poultry consumption. The coefficients of beef, pork, and other meats are positive but not statistically significant. This indicates no measurable impact on poultry consumption by beef, pork, and other meat consumption.

4.4.1. High-income group

Analysis of the statistical results, by income group, reveals that the poultry consumption of the high-income group is positively and significantly impacted by the trade openness, average surface temperature, and pork consumption at the 1 % significance level. This might suggest that consumers tend to include multiple meat types in their diets simultaneously, and more liberalised trade policies promote poultry imports, stimulating consumption levels. Regions with rising average surface temperatures might shift consumption towards poultry due to its comparatively lower fat content, which makes it more suitable for warmer climates. However, this study demonstrates that per capita GDP and other meat consumption have a statistically significant negative impact on poultry consumption, at the 1 % level. Further increase in income might not impact PC as consumers have already reached their preferred levels of meat intake, and as consumption of other meats rises, PC may fall due to dietary differences.

This result contradicts findings of [31], that higher income individuals tend to consume white meat more frequently, as observed in Latvia and with [66], who reported that increasing income significantly boosts poultry and pork consumption in China, both of which are high-income countries. However, a significant negative correlation between poultry and other meat sources such as pork, beef, and mutton was observed in China [66]. There was no significant difference in meat intake based on household income in the UK, a high-income country, which supports our finding that an increase in other meat consumption and income reduces poultry consumption [58].

The coefficients for sheep, goat, and beef consumption are positive but insignificant, meaning these variables do not significantly impact poultry consumption. This could be due to these meats being consumed by different demographic groups, where there may be parallel increases, but the correlation is weak.

4.4.2. Upper-middle income group

Random effect estimate of the upper-middle income group suggests average surface temperature has a positive and statistically significant effect on poultry consumption at the 10 % significance level which might be due to poultry is generally more heat tolerant in terms of production and better suited for lighter meals that are preferred in hotter regions, trade openness has a negative and statistically significant impact on poultry consumption at the 5 % significance level. Unlike in high-income countries, in upper-middle-income countries, the cause of the trade openness impact is to decrease poultry consumption, as trade openness improves access to non-meat substitutes, poultry consumption is diverted away.

Sheep and goat consumption, pork consumption and other meat consumption have a positive, insignificant impact on poultry consumption. The positive but statistically weak association suggests that pork, sheep and goat, and other meat types may be consumed in parallel, rather than one replacing the other, cultural and religious factors, regional popularity, and low cost leading to independent consumption patterns. Compared to these variables, per capita GDP and beef consumption in random effect estimates have a negative and insignificant effect on poultry consumption. These findings imply that the increase in per capita GDP and beef consumption slightly decreases poultry consumption, but the results lack statistical confidence for the upper-middle income group. Possibly due to cultural preferences or religious restrictions, dietary shifts between beef and poultry do not strongly influence levels of poultry consumption.

However, price fluctuations in other meat categories can influence poultry demand. Increasing beef prices has led to higher chicken meat consumption in Turkey [17]. Even though per capita GDP had an insignificant impact, some past studies suggest that income levels do play a role in poultry consumption. Income was found as a statistically significant determinant of MC in Turkey [28]. An increase in poultry consumption was observed with family size and monthly income in Iraq, [41]. So both Turkey and Iraq, being upper-middle-income countries, findings of the current study contradict the past studies, which have focused on a single country instead of the upper-middle-income group.

4.4.3. Lower-middle income group

According to the statistical results of the lower-middle-income group in the POLS model, pork consumption has a significantly positive impact on poultry consumption at the 10 % significance level. This suggests that increasing pork consumption may lead to higher poultry consumption. Consumers may increase meat consumption, particularly pork and poultry, due to their cost-effectiveness and cultural acceptance in certain regions.

Per capita GDP, average surface temperature, other meat, and sheep and goat consumption have a positive and insignificant impact on poultry consumption. As per capita GDP, average surface temperature, other meat consumption, and sheep and goat consumption reach higher values, a slight increase in poultry consumption can be seen, yet the impact is not statistically significant. Poultry is often the first meat added to diets as purchasing power improves, but this shift may be gradual and uneven. Although poultry consumption is better suited to warmer climates, infrastructure, market access, and storage capacity may influence availability and preference in these economies. The positive relationship between other meat consumption, Sheep and goat consumption, and poultry consumption in lower-middle-income countries suggests that other meat types may be consumed alongside poultry, but the effect isn't consistent enough to be statistically meaningful, which might be possibly due to its seasonal nature.

The findings on the insignificance of income (per capita GDP) contradict previous studies that identified income as a key determinant of poultry consumption in lower-middle-income countries. For instance, income was a significant factor in determining poultry consumption in Vietnam, a lower-middle-income country [45]. Similarly, it was reported that income significantly influences poultry consumption in Srinagar, India [61].

In Chennai, India, it was found that household income positively influences poultry consumption, along with factors such as family size, education, and the presence of children and elderly members [62]. Such slight differences in findings may be attributed to variations in data coverage, time periods, or underlying economic conditions.

On the other hand, trade openness and beef consumption exhibit adverse but statistically insignificant effects on poultry consumption. This suggests that higher trade openness and beef consumption slightly decrease poultry consumption, but the statistical evidence is not enough to confirm a considerable impact. Trade openness may not fully benefit poultry markets in lower-middle-income countries due to

competitiveness and compliance with international food standards. Also, beef is more expensive and less accessible, making it a less effective substitute for poultry, and beef consumption may be limited to wealthier segments or special occasions. Additionally, R^2 for the lower-middle-income group is 0.0443, meaning that the independent variables only explain approximately 4.43 % of the poultry consumption variance.

4.4.4. Low-income group

POLS model estimates in the low-income group indicate that pork consumption positively and statistically significantly impacts poultry consumption. This implies that rising pork consumption is closely linked to rising consumption of poultry in low-income countries. Pork is often more affordable than beef and may serve as a complementary protein source alongside poultry. Conversely, variables such as trade openness, average surface temperature, and sheep and goat consumption also display positive relationships with poultry consumption. Still, these effects are statistically insignificant. Though trade openness, SGC, and temperature may influence poultry consumption by increasing access to poultry-related products, availability, and consumer preference, limited purchasing power or weak regulatory systems, and local customs in low-income settings may prevent them from having a strong direct impact.

Additionally, per capita GDP, beef consumption, and other meat consumption exhibit negative and statistically insignificant impacts on poultry consumption. This indicates that an increase in per capita GDP or consumption of beef or other meats is not significantly associated with higher poultry consumption in low-income countries.

5. Conclusion and policy implications

Most past empirical studies have examined the variables of this study individually rather than collectively analysing the combined impact on poultry consumption. The variable average surface temperature was often excluded in existing literature, and its direct impact on poultry consumption was not highlighted.

It is important to note that the differencing of non-stationary variables means that the estimated coefficients capture the effects of changes in the independent variables on poultry consumption, rather than the effects of their absolute levels. As a result, the policy implications related to short-term adjustments, such as annual shifts in GDP, Trade openness, or Temperature, rather than long-term structural differences between countries. Therefore, policymakers should interpret the results as guidelines for how incremental changes in these drivers are likely to influence poultry consumption trends in the near term, and exercise excessive caution in extrapolating these effects to sustained or structural changes over longer horizons.

This study engages a Panel regression approach, sectioning based on income levels to seize the differentiated impact of these variables on poultry consumption, for 21 years from 2000 to 2021. The fixed effect, random effect, and POLS models were applied for statistical analysis. These conclusions led to both positive and negative outcomes and mixed outcomes. Across all 40 countries, high-income and upper-middle average surface temperature was found to significantly impact poultry consumption significantly. In lower middle-income countries, sheep and goat consumption showed a significant impact using POLS, while in low-income countries, pork consumption also emerged, having a significant positive impact.

Meaningful contributions to governments are provided from this research to design policies and take steps necessary to address the overconsumption of meat in such areas and encourage people to make dietary shifts to promote sustainable development goals and health trends. The study will provide vital information for nations facing changes in consumption by shedding light on how trade openness influences poultry meat imports and exports. In areas where poultry consumption is increasing due to increasing income, authorities or policymakers may find this study insightful for making decisions to balance economic growth with health and environmental considerations. Poultry indirectly impacts ecological sustainability pertaining to greenhouse gas emissions, water resources, and land use. This study will discuss how poultry consumption must be altered to promote environmental sustainability. It will be insightful for economists as well as environmentalists to gain proper knowledge on this aspect of poultry consumption. The conclusion of this study leads to the need for policy implications as discussed in the following paragraphs, followed by the limitations and future research.

Promoting poultry as a protein-rich food can be suggested as a sustainable alternative, to mitigate the decline in poultry consumption due to increasing per capita income. Subsidies for poultry should be further encouraged. Moreover, import standards should be tightened and local meat should be given priority to minimise the increase in chicken consumption through trade openness. It is also shown that the increase in temperature increases the consumption of poultry meat. It is necessary to establish a cooling system and impose zoning regulations for chicken production. It is shown that the increase in pork consumption affects the increase in chicken meat. Taxes should be imposed and tightened on pork and other meat due to the decrease in chicken meat consumption This can be shown that these schemes can help high-income countries to properly control meat consumption.

It is shown that as trade openness increases, poultry consumption decreases, and as temperature increases, poultry consumption increases. Therefore, by paying more attention to building a system that guarantees local chicken meat, local chicken consumption can be increased by providing high-quality meat, thereby helping to uplift local farmers and maintain consumer confidence. Furthermore, implementing tariffs on imported chicken can also be a reason to increase national chicken consumption. It is pointed out that increasing surface temperature will increase the consumption of pork. Since meat production can cause temperature increases, local farmers can be given proper understanding to control it, for an example; awareness sessions, and to create substitutes for chicken to reduce chicken consumption in the face of extreme heat, and to promote plant-based foods. These schemes can help to achieve sustainable policies in upper middle countries.

It has been shown that pork consumption increases in both lower middle- and low-income countries when income levels increase. It might be due to the fact that pork and chicken are more affordable than other meat, considering people's income level. It is also suggested that increasing regulations to prevent future growth, imposing certain limits on pork, directing to obtain quality certificates, and establishing environmental regulations can prevent the impact of chicken consumption on rising pork consumption in lower middle income and low-income countries. It can also be pointed out that it is essential for lower middle- and low-income countries to adopt sustainable policies. For this, sustainable concepts can be achieved through issues such as maintaining balanced poultry consumption, establishing quality assurance systems to test the quality of poultry, adopting sustainable meat production food policies, and increasing food safety by improving the quality of animal feed.

Cross-country evidence suggests that demand for meat increases with trade and economic development, while sheep and goat consumption declines. Therefore, policies should ensure that food systems are environmentally sustainable and nutritionally aligned with a country's food preferences.

However, the study has several limitations. The study was only confined to a specific time period due to the data unavailability; this did not fully capture the long-term consumption trends in meat consumption patterns of people. In addition to the relationship between poultry consumption in the light of the main independent variables, namely per capita GDP, trade openness, and average surface temperature, the dietary patterns shaped by cultural preferences, habits of people, religious influences, climate conditions and government policies may also impact poultry consumption significantly but are not directly included due to difficulties in quantification. The cause of omitting the variables like attitudes, beliefs, cultural norms, religious practices were because they

are qualitative. Most of the previous research considered the aforementioned variables were incorporated quantifiably, but on a small scale, this study advances the existing literature by adapting a global perspective, unlike many studies that were limited to regional levels. Also, due to endogeneity, which is referred to where the effect of the independent variables on poultry consumption cannot be casually interpreted as it includes omitted causes that leads to biased estimates [11]. For example, per capita GDP and trade openness are independent variables that impact poultry consumption, but poultry consumption itself could also impact per capita GDP through agricultural sectors or trade through meat import or export flows. Moreover, this study excludes external factors that may also significantly impact poultry consumption, such as technological advancements, urbanisation, and ethical concerns about animal welfare, this could be relevant for future research. Despite the limitations, the findings offer valuable insights, providing meaningful direction for the study.

Given these limitations, future research could benefit from an understanding of how these independent variables collectively influence changes in poultry consumption, particularly in enhancing econometric models that investigate the contribution of economic and environmental factors. Based on these findings, further research into the subject area can be conducted, making this study important for future researchers and academics.

CRediT authorship contribution statement

Ishara Sammani: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bimba Yeshini:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sayuni Siriwardhane:** Writing – original draft, Validation, Formal analysis, Data curation. **Kaveesha Pasindu:** Visualization, Data curation. **Ruwan Jayathilaka:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization.

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.sftr.2025.101485.

Data availability

All data generated or analysed during this study is available as a supplementary information file.

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