

Persistence assessment of beef and buffalo meat consumption in OECD countries: A fractional integration perspective

Luis A. Gil-Alana^{a,b,*,1}, Sakiru Adebola Solarin^c, Carmen Lafuente^d,
María Jesús González-Blanch^d

^a University of Navarra, Faculty of Economics, DATAI and NCID, Pamplona, Spain

^b Universidad Francisco de Vitoria, Madrid, Spain

^c Multimedia University, Malaysia

^d Universidad Francisco de Vitoria, Madrid, Spain

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ABSTRACT

The paper investigates the persistence of beef and buffalo meat consumption in 30 countries. We use two measures of persistence, autoregressions and fractional integration. The results indicate very heterogeneous behaviour across countries with some positive and negative trends and some countries displaying mean reversion while others show a lack of it. Nevertheless, the results reveal strong persistence in beef and buffalo meat consumption across OECD countries, with most autoregressive and fractional parameters exceeding 0.5. The persistence is especially pronounced in Japan, Germany, Italy, and Spain, whereas countries such as New Zealand and the Netherlands show faster mean reversion. These findings suggest that changes in meat consumption habits evolve slowly over time, reflecting structural, cultural, and geographical factors. Consequently, long-term policies should be accorded priority in the process of reducing beef and buffalo meat consumption for health or environmental reasons.

1. Introduction

Beef is considered a major source of protein, and its consumption is associated with its considerable health benefits, as it provides essential nutrients such as high-quality protein, iron, zinc, and vitamin B12. (Magalhaes et al., 2023). In recent years, buffalo meat has emerged as an interesting alternative protein source (Vaz et al., 2024). Buffalo meat is gaining worldwide attention due to its excellent nutritional profile and health-promoting properties. Because it contains less fat, less cholesterol, and fewer calories than some other forms of red meat, buffalo meat is considered one of the most wholesome red meat options available for human consumption (Singh et al., 2025).

Nonetheless, there are studies that suggest that excessive intake of beef and buffalo meat may raise the likelihood of developing chronic diseases such as diabetes, cancer and cardiovascular diseases, among others (Milford et al., 2019). Moreover, the consumption of beef and buffalo meat has a significant environmental impact associated with livestock production which not only contributes to higher greenhouse

emissions, but also affects the water footprint, water pollution and water scarcity (González et al., 2020).

The Lancet Commission emphasized the need for a dietary transformation, proposing a global reduction of more than 50% in beef and buffalo meat consumption, particularly beef, as an essential measure to improve human health and protect the environment (Willett et al., 2019). Likewise, the United Nations has advised dietary modifications (which include the reduction in beef and buffalo meat consumption) to support both environmental sustainability and human health. For instance, the United Nations guidance to implement global diets with reduced greenhouse gas emissions entails a decrease in beef consumption. (Parzianello & Carvalho, 2024).

Given the importance of beef and buffalo meat on health and environmental effects, the main objective of this study is to examine the trend and persistence of the beef and buffalo meat consumption series across 30 Organization for Economic Co-operation and Development (OECD) countries over the period 1961–2022. Using fractional integration techniques, this study contributes to the literature by identifying

* Correspondence to: University of Navarra, Faculty of Economics and ICS, Pamplona E-31080, Spain.

E-mail address: alana@unav.es (L.A. Gil-Alana).

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the countries in which beef and buffalo consumption series exhibit stationarity and those in which the series are non-stationary. Fractional integration techniques capture the accumulation of consumption habits across a period of time, essentially reflecting the inertia in altering diet-related choices. Using this method, it can be shown that the current consumption level is not isolated but is based on accumulated habits over time. Modeling consumption habits within the framework of fractional integration approach permits a substantial extent of flexibility (Wen et al., 2024). In addition, this study examines the persistence of beef and buffalo meat consumption, which has not been extensively explored in the current literature. Understanding the trends in beef and buffalo meat consumption is particularly relevant for researchers and public health professionals who aim to reduce the global burden of chronic diseases (Rasin et al., 2025).

The focus on OECD countries is for several reasons. The average beef and buffalo meat consumption was 18.52 kg per capita in OECD countries while the global average was just 9.33 kg per capita in 2022 (Our World in Data, 2025). Some OECD countries have undergone an increase in beef and buffalo meat consumption. For instance, average beef and buffalo meat consumption in Greece rose from 5.11 kg per capita in 1961–15.68 kg per year per capita in 2022 (Our World in Data, 2025). The beef and buffalo market often faces outbreak of diseases in OECD countries, which can disrupt their consumption. Bovine spongiform encephalopathy (BSE) or “mad cow” disease was experienced in Canada (in 1993), the United States (in 2003, and 2005) and Chronic wasting disease (CWD) in Norway (in 2016) (Mysterud et al., 2025).

The structure of this paper is as follows: Section 2 presents the literature review; Section 3 describes the methodology; Section 4 introduces the dataset; Section 5 reports the empirical results; and Section 6 provides the conclusions.

2. Literature review

Although meat provides essential nutrients, its high consumption has been linked to an increased risk of several chronic diseases (Godfray et al., 2018). Changing meat consumption habits is a complex challenge that requires identifying the factors influencing meat-eating behaviors and developing effective policies and interventions (Baruselli et al., 2025).

The literature suggests that meat consumption is influenced by population changes, increased health and environmental concerns, income and relative prices, among others (Resurreccion, 2004; Brewer, 2012). Recent reviews also emphasize the role of specific consumer segments, such as athletes or individuals with high protein intake, whose choices are shaped by nutritional goals, cultural influences, and ethical motivations (Siddiqui et al., 2024).

While research on beef and buffalo consumption persistence has not yet to be studied extensively in the literature, the concept of persistence can be framed through habit formation theory, which suggests that consumer utility is derived not only from current consumption but also from the accumulated stock of past consumption habits. This effect tends to be stronger among low-income and younger groups, although its influence has shown signs of declining over time (Wen et al., 2024).

Commodity prices are also considered particularly important, as they influence consumption patterns and subsequently, the behavior of beef consumers (Bielik et al., 2021). The persistence of commodity prices has been widely examined in the literature. In this regard Kellard and Wohar (2003), studied trends in 24 primary commodity prices from 1900 to 1998 to test the Prebisch-Singer hypothesis. They applied Lumsdaine and Papell's (1997) unit root tests and found that 23 commodities are trend-stationary, suggesting much lower persistence in prices than previously reported and providing more scope for stabilization mechanisms. These results are consistent with the study by Ghoshray et al. (2014), which analyzed the long-term dynamics of 24 primary commodity prices from 1900 to 2008 and found that most followed trend-stationary patterns. Their analysis indicated negative trends for

rice, wheat, sugar, and hides, and positive trends for beef, lamb, and timber. On the other hand, several studies have applied fractional integration techniques such as the work of Gil-Alana and Font de Vil-lanueva (2022) that analyzed the persistence of global prices for 15 commodity categories over the period 1960–2018. Results showed high persistence in most series and identified structural breaks linked to global economic crises.

Other studies such as Tiwari et al. (2015) analyzed the nonlinear mean reversion behaviour in the prices of 47 agricultural commodities in India during the period 2000–2013. Using several nonlinear unit root and stationarity tests, the authors found that food grain prices follow a unit root process with drift, whereas the prices of other agricultural commodities (including eggs, meat, and fish) tend to revert to their mean values. On the other hand, studies such as Ghoshray (2019) examined how the persistence of shocks affects international commodity prices (corn, soybeans, milk, pork, wheat and cattle) from 1960 to 2016, using an extended dataset from Wang and Tomek. The research concludes that, although results are mixed, the balance of evidence suggests that agricultural price shocks are permanent in nature.

Likewise Awaworyi-Churchill et al. (2022), analyzed prices of eight commodities from 1300 to 2019 using sequential tests, finding that most have a unit root, so shocks are likely to be permanent and long-term cycles are highly persistent. Along similar lines Landajo and Presno (2022), examined the trend stationarity of a set of renewable commodities over the period 1900–2018, concluding that stationarity was rejected for livestock commodities, particularly lamb and beef.

More recently Solarin et al. (2025), analyzed the prices of 17 renewable agricultural commodities, including beef, over the period 1900–2022. Using fractional integration techniques, their results provided evidence of mean reversion across all commodities.

Research on the persistence of beef and buffalo meat consumption is an emerging field of study as it provides valuable insights for policy-makers. While red meat intake appears to be declining, its consumption in other countries continues to pose a health risk, particularly when consumed in large quantities (Rasin et al., 2025). Scholars and policy-makers are increasingly advocating a reduction in beef and buffalo meat consumption, and promoting initiatives designed to enhance public health, the environment and animal welfare (Bonnet et al., 2020). Some policies include government incentives through fiscal measures, such as meat taxes, as well as administrative or regulatory instruments, such as restrictions on advertising or availability of meat products and the promotion of plant-based alternatives in public institutions. Additionally, informational and behavioral instruments can be employed to encourage shifts in consumer preferences. Also, in the long term, developing educational policies can help foster more sustainable consumption habits and support environmental goals (Bonnet et al., 2020; James et al., 2022; Bonnet & Coinon, 2024; Parzianello & Carvalho, 2024).

3. Data

This study draws on longitudinal data from 30 member countries of the OECD, obtained from Our World in Data (2025).² The dataset comprises annual time series on beef and buffalo meat consumption, measured in kilograms per capita, spanning the period 1961–2022. Changes in beef and buffalo meat consumption are influenced by economic, dietary, and environmental factors. Over the past six decades, the

² One of the limitations associated with the current data in Our World in Data (2025) is that it does not provide separate figures for either beef consumption or buffalo meat consumption. Aggregated series might blur the difference between the characteristics of beef consumption and buffalo meat consumption. Although buffalo meat consumption is relatively lower than beef consumption in many countries (Chandra et al., 2025), we are unable to provide distinct results for the different meat categories.

combined effects of income growth, urbanization, and global market integration have reconfigured consumer demand, particularly in emerging economies where dietary westernization has intensified the intake of animal-source foods. Conversely, in high-income contexts, increasing public awareness of the environmental footprint of livestock production, along with evolving health narratives, has contributed to a gradual moderation or diversification of meat consumption profiles. (OECD, 2025). Analyzing these long-term trajectories provides critical insights for the formulation of coherent policies across the agri-food, public health, and climate governance domains.

Table 1 displays several statistical measures that help describe the situation of beef and buffalo meat consumption in OECD countries during the study period 1961–2022. In both Table 1 and Fig. 1, we observe that some countries—such as Australia, Canada, New Zealand, and the United States—show average per capita consumption levels significantly higher than the OECD average (20.37 kg per capita).

In the same Table 1, we observe that the average consumption in the four countries mentioned is relatively stable or shows acceptable stability, as they present Pearson coefficients of variation (CV) below 30. This is not the case for New Zealand, which, with a CV of 42.65, shows high variability in its average consumption. This indicates significant changes, possible crisis episodes, or consumption spikes. Although Korea, Poland, and Turkey are the countries with the highest CV values across the OECD (72.42, 62.40, and 58.62, respectively), in these cases, the greater dispersion may be attributed to their very low average consumption levels, meaning that small absolute variations result in large relative changes.

Continuing with Table 1, although all series are weakly stationary (i.e., $|\text{ACF}_1| < 1$), the first-order partial autocorrelation coefficient (ACF_1) exceeds 0.7 in all cases, indicating a high degree of persistence in annual per capita consumption of beef and buffalo meat across OECD countries. This suggests that year-to-year fluctuations are relatively minor, and that consumption shocks tend to have enduring effects rather than dissipating quickly. Such behavior aligns with the slow adaptation of dietary patterns, supply-side constraints, and long-term structural factors influencing demand for meat.

If we analyze the trend in beef and buffalo meat consumption, 16 out of the 30 OECD countries display a negative slope (Table 1), indicating a gradual decline over time.³ The OECD average series, shown in Fig. 2 in both levels and logarithmic form, confirms this general pattern: per capita beef and buffalo meat consumption rose steadily—particularly during the early 1970s—until reaching a peak around 1976 and has followed a persistent downward trajectory thereafter. In 1976, several countries were still grappling with the consequences of the 1973 oil crisis, including high inflation, rising unemployment, and declining purchasing power.

Inflation reached double-digit figures between 1974 and 1975, with unemployment rates above 7%. This eroded purchasing power and affected the consumption of basic goods (Kramer, 2025) and the increase in cereal prices indirectly affected the meat market (Gerlach, 2024). Inadequate monetary policies by the UK and the US aimed at combatting inflation reduced purchasing power, which affected beef and buffalo meat consumption (Nelson, 2022). Inflation, unemployment and reduced purchasing power were factors that likely contributed to a reduction in the consumption of higher-cost goods such as beef and buffalo meat. In addition to prices, other factors that may justify the decrease in beef and buffalo meat consumption are the change in eating behavior of developed economies reflecting growing environmental and health concerns.

³ Note, however, that this result should be taken with caution since the trend is estimated here under the assumption of a very simple model with independent and identically distributed (i.i.d.) errors.

4. Methodology

We are interested in testing for persistence. Two alternative approaches are considered here. On the one hand, one based on a simple autoregressive process of order 1, i.e., an AR(1), and the other one using a fractionally integrated or I(d) process. In both cases, we allow for potential trends in the data. Thus, the first model under consideration is:

$$y(t) = \beta_0 + \beta_1 t + x(t), \quad (1 - \rho L)x(t) = u(t), \quad t = 1, 2, \dots \quad (1)$$

where $y(t)$ represents the observed data at time t ; β_0 and β_1 unknown coefficients referring respectively to an intercept and a linear time trend, and $x(t)$ are the regression errors. The second equation indicates the AR(1) process where ρ is the AR coefficient; L is the lag operator, i.e., $Lx(t) = x(t-1)$, and $u(t)$ is a white noise process. The reason for using a simple specification such as the AR(1) for the short run dynamics is that this AR coefficient may describe quite well all the time dependence of the data. In fact, higher AR orders were also considered, and taking the sum of the coefficient as an alternative measure of persistence produced almost identical results to those reported in the paper.

The second specification replaces the AR structure by a fractional one, such that the model is now:

$$y(t) = \beta_0 + \beta_1 t + x(t), \quad (1 - L)^d x(t) = u(t), \quad t = 1, 2, \dots \quad (2)$$

where d can be any real value.

The main distinction between the two approaches is the way the series behave in the presence of shocks since the impulse responses in the AR case decays exponentially fast, while in the fractional structure they decay in a hyperbolically slower way. In a certain sense, the second specification can invalidate the first one, since the AR specification in (1) imposes that $x(t)$ is an integrated of order 0 or I(0) process, and this hypothesis is precisely tested in (2) since d can be any real value and thus including the value $d = 0$.

The estimation is conducted through the Whittle function in the frequency domain, and for the confidence intervals we rely on a simple version of a testing procedure developed in Robinson (1994) and widely used in the context of fractional integration of the form as in (2). In particular, it is a Lagrange Multiplier (LM) procedure that tests the null hypothesis $H_0: d = d_0$ in (2) where d_0 can be any real value. Its functional form can be found in Gil-Alana and Robinson (1997) and based on the LM principle, it has an asymptotical standard Normal distribution. Moreover, it is supposed to be the most efficient method in the Pitman sense against local departures from the null.

5. Results

Table 2 reports the results for the AR(1) model using the original data. The table displays the estimates of the intercept (in column 2), the time trend (column 3) and the AR coefficients (column 4) for each series under investigation. The first thing we observe is that the time trend is statistically significantly negative in 16 countries; for 12 it is positive and it is insignificant in another two (Greece and Ireland). The most negative trends are observed in the cases of Australia (with $\beta_1 = -0.415$) and New Zealand (-0.727). Looking now at the AR coefficients the majority of them are very high and close to 1, the smallest values corresponding to New Zealand ($\rho = 0.327$) and Netherlands (0.344). On the other hand, the highest values, and thus the highest levels of persistence occur in Japan (0.959), followed by Germany (0.953), Italy (0.945) and Poland (0.942).

Table 3 displays the results for the logged values. We observe that they are fairly similar. 16 countries display a positive time trend; 13 a negative one and only Ireland presents now an insignificant trend. The highest degrees of persistence are observed in Japan ($\rho = 0.957$), Italy (0.946) and Germany (0.943).

Table 1

Beef and buffalo meat consumption in OECD countries-Statistical measures.

Country	Mean	Median	Coefficient of variation	Slope	Skewness	Kurtosis	autocorrelation coefficient
Australia	44.64	43.50	25.42	-0.41	1.28	2.51	0.82
Austria	20.26	20.22	16.20	-0.12	-0.05	-0.93	0.91
Canada	36.08	34.61	17.76	-0.31	0.35	-0.50	0.94
Chile	20.13	19.72	21.13	0.18	0.58	0.41	0.83
Colombia	18.46	18.50	12.30	-0.09	-0.31	-0.39	0.81
Costa Rica	17.12	17.02	21.14	-0.06	0.38	-0.61	0.75
Denmark	20.37	19.63	25.81	0.23	0.06	-1.25	0.94
Finland	20.07	19.51	9.27	-0.06	0.58	-0.76	0.83
France	27.94	28.14	10.78	-0.12	-0.10	-0.92	0.91
Germany	18.23	20.08	24.53	-0.20	-0.12	-1.73	0.98
Greece	18.11	18.77	25.87	0.05	-0.04	2.04	0.75
Hungary	13.19	15.13	43.93	-0.30	-0.17	-1.66	0.92
Iceland	12.18	12.31	19.60	0.08	-0.37	0.15	0.75
Ireland	22.82	22.08	20.45	0.00	0.62	-0.54	0.78
Israel	21.08	19.56	30.15	0.29	0.39	-0.89	0.76
Italy	23.09	24.15	15.83	-0.06	-0.85	-0.67	0.88
Japan	6.89	8.35	44.84	0.15	-0.41	-1.30	0.96
Korea	8.00	7.50	75.42	0.32	0.41	-1.16	0.94
Mexico	13.95	15.12	22.94	0.14	-0.35	-1.32	0.95
Netherlands	18.90	18.77	12.43	-0.10	0.04	-1.22	0.70
New Zealand	38.32	37.71	42.65	-0.73	0.70	0.33	0.75
Norway	18.24	18.76	12.01	0.08	-0.74	-0.57	0.91
Poland	10.53	11.10	62.40	-0.28	-0.10	-1.26	0.96
Portugal	14.43	14.33	28.32	0.21	-0.22	-0.76	0.90
Spain	12.34	12.41	16.40	0.07	-1.02	1.21	0.86
Sweden	19.90	19.24	13.93	0.11	0.27	-1.31	0.93
Switzerland	23.69	24.01	13.11	-0.14	-0.09	-1.53	0.92
Turkey	6.44	5.28	58.62	0.16	1.34	0.95	0.87
United Kingdom	20.90	21.10	13.26	-0.12	-0.10	-1.12	0.87
United States	44.77	43.77	12.97	-0.26	0.22	-0.65	0.95
OECD	20.37	20.06	7.59	-0.04	1.04	1.29	0.87

Note: Countries highlighted in red exhibit a coefficient of variation (CV) above 25%, indicating higher relative variability in per capita beef and buffalo meat consumption. Countries in green display a negative consumption trend over the sample period.

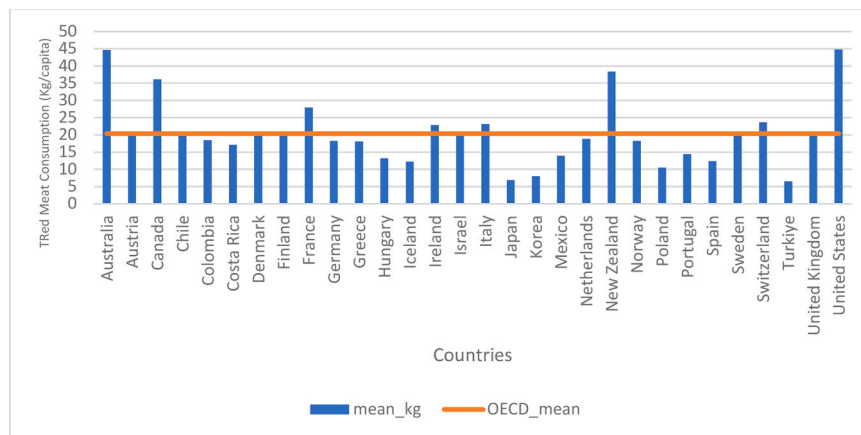
**Fig. 1.** Beef and buffalo meat consumption in OECD countries.

Table 4 reports the estimates of α and β in a context where the order of integration of $x(t)$ is also estimated from the data. The first thing we observe in this table (in its last column) is that the estimates of d display confidence bands with positive values in all cases. This indicates that the differencing parameters are all significantly positive, implying that the hypothesis of short memory or $I(0)$ behavior is clearly rejected in all the series. We observe that there are seven countries with estimated values of d above 1: Spain, Italy, Canada, Poland, Germany, USA and Japan; however, only for two countries, Germany and Japan, is this estimate significantly higher than 1. When examining the estimated values of the fractional differencing parameter (d), it is noteworthy that Canada and Mexico, as well as Spain and Italy, share identical levels of persistence in red meat consumption. This similarity may reflect the influence of common geographical and structural factors. In North America, both

Canada and Mexico operate within an integrated market framework and are exposed to similar trade conditions, supply chains, and price dynamics that shape consumer behavior. Similarly, Spain and Italy belong to the Mediterranean region, where dietary preferences, cultural attitudes toward meat, and the gradual shift toward alternative protein sources tend to follow comparable paths. These shared regional characteristics may help explain why the dynamic adjustment of meat consumption exhibits similar persistence across these countries. Apart from these two countries, there are another 12 where the unit root null hypothesis is rejected, in this case in favor of mean reversion, i.e., $d < 1$. They are Netherlands ($d = 0.28$), New Zealand (0.29), Israel (0.43), Hungary (0.50), Chile (0.58), Costa Rica (0.62), Iceland (0.65), Korea (0.68), Greece (0.71), the UK (0.72), Finland (0.78) and Switzerland (0.79). For all the others, though the estimate of d is smaller than 1, the I

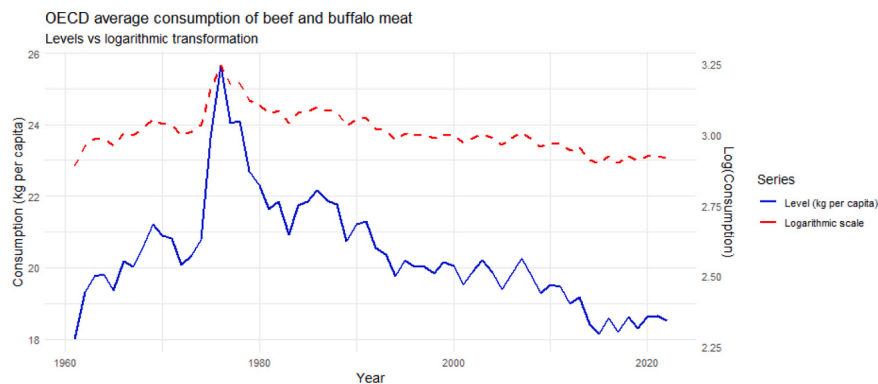


Fig. 2. OECD consumption: levels vs logarithms.

Table 2

Estimated coefficients in an AR(1) model with a linear time trend. Original data.

Country	α (t-value)	β (t-value)	AR coefficient
Austria	24.185 (39.66)	-0.125 (-7.40)	0.886
Australia	57.712 (26.53)	-0.415 (-6.91)	0.717
Canada	45.739 (55.46)	-0.306 (-13.47)	0.860
Chile	14.521 (20.42)	0.178 (9.07)	0.665
Colombia	21.241 (51.36)	-0.088 (-7.72)	0.734
Costa Rica	18.955 (21.47)	-0.058 (-2.39)	0.738
Denmark	13.102 (15.99)	0.230 (10.19)	0.844
Finland	22.016 (57.85)	-0.061 (-5.87)	0.781
France	31.834 (61.68)	-0.123 (-8.67)	0.849
Germany	24.599 (37.25)	-0.202 (-11.08)	0.953
Greece	18.105 (30.68)	—	0.810
Hungary	22.591 (41.49)	-0.298 (-19.86)	0.570
Iceland	9.687 (19.85)	0.079 (5.88)	0.499
Ireland	22.816 (38.82)	—	0.798
Israel	12.098 (12.70)	0.285 (10.84)	0.529
Italy	25.037 (28.21)	-0.062 (-2.52)	0.945
Japan	2.212 (5.63)	0.148 (13.71)	0.959
Korea	-2.195 (-5.66)	0.323 (30.24)	0.745
Mexico	9.523 (19.13)	0.140 (10.23)	0.907
Netherlands	21.968 (55.21)	-0.097 (-8.86)	0.344
New Zealand	61.229 (24.62)	-0.727 (-10.59)	0.327
Norway	15.761 (37.02)	0.078 (6.69)	0.870
Poland	19.335 (17.97)	-0.279 (-9.41)	0.942
Portugal	7.735 (21.40)	0.212 (21.28)	0.732
Spain	10.189 (24.87)	0.068 (6.02)	0.911
Sweden	16.552 (32.41)	0.106 (7.54)	0.871
Switzerland	28.086 (60.69)	-0.139 (-10.93)	0.839
Turkey	1.302 (2.15)	0.163 (9.79)	0.873
United Kingdom	24.683 (55.96)	-0.120 (-9.86)	0.748
United States	53.065 (62.26)	-0.263 (-11.19)	0.885

(1) hypothesis cannot be rejected. For the time trends, five countries (Chile, Israel, Korea, Portugal and Turkey) present a positive trend, while for another five (Hungary, Netherlands, New Zealand, Switzerland and the UK) a negative trend is observed.

Table 5 reports the results for the logged values. There are seven countries with values of d above 1 (Mexico, Canada, Germany, Spain, Italy, USA and Japan) though this time the unit root null hypothesis cannot be rejected in any single case since the intervals include the value of 1. Mean reversion ($d < 1$) occurs in 13 countries, the same 12 as for the original data along with Australia. In any case, in both tables, it seems that the less persistent series correspond to the same three countries: New Zealand, Netherlands and Israel. Positive trends are found in the same five countries as for the original data (Chile, Israel, Korea, Portugal and Turkey) and seven display a negative trend (the same five as before, Hungary, Netherlands, New Zealand, Switzerland and the UK, along with Australia and Poland).

As the papers on beef and buffalo meat consumption are effectively non-existent, it is unviable to undertake direct comparison between outcomes of the present paper with previous studies. Nevertheless, the

Table 3

Estimated coefficients in an AR(1) model with a linear time trend. Logged data.

Country	α (t-value)	β (t-value)	AR coefficient
Austria	3.200 (106.34)	-0.0065 (-7.85)	0.879
Australia	4.074 (97.27)	-0.0096 (-8.36)	0.642
Canada	3.844 (184.06)	-0.0087 (-15.11)	0.850
Chile	2.712 (73.90)	0.0085 (8.39)	0.591
Colombia	3.065 (132.50)	-0.0049 (7.80)	0.751
Costa Rica	2.925 (56.93)	-0.0034 (-2.40)	0.738
Denmark	2.613 (60.55)	0.0116 (9.74)	0.817
Finland	3.091 (167.64)	-0.0030 (-5.98)	0.774
France	3.469 (191.13)	-0.0046 (-9.19)	0.858
Germany	3.234 (83.84)	(-10.80)	0.943
Greece	2.707 (35.78)	0.0047 (2.25)	0.892
Hungary	3.288 (64.30)	-0.0026 (-18.56)	0.703
Iceland	2.258 (50.25)	0.0070 (5.63)	0.596
Ireland	3.107 (124.31)	—	0.806
Israel	2.584 (53.03)	0.0132 (9.87)	0.398
Italy	3.216 (76.26)	-0.0028 (-2.48)	0.946
Japan	0.870 (11.24)	0.0290 (13.58)	0.957
Korea	-0.053 (-0.80)	0.0547 (30.04)	0.789
Mexico	2.260 (59.22)	0.0109 (10.43)	0.905
Netherlands	3.096 (147.93)	-0.0053 (-9.08)	0.344
New Zealand	4.201 (72.76)	-0.0205 (-12.86)	0.250
Norway	2.749 (112.37)	0.0046 (6.88)	0.868
Poland	3.621 (17.67)	-0.0543 (-9.61)	0.835
Portugal	2.115 (60.80)	0.0161 (16.75)	0.827
Spain	2.296 (59.94)	0.0063 (6.01)	0.917
Sweden	2.817 (108.41)	0.0052 (7.23)	0.866
Switzerland	3.347 (173.44)	-0.0060 (-11.40)	0.830
Turkey	0.992 (13.19)	0.0231 (11.16)	0.793
United Kingdom	3.210 (143.08)	-0.0057 (-9.20)	0.762
United States	3.981 (216.50)	-0.0059 (-11.79)	0.893

results do not align with the proposition of Smyth and Narayan (2015) that series with big numbers tend to be more persistent and smaller series tend to be more mean reverting. The strongest persistence is found in Japan, Germany, Italy, and Poland, but only Italy is among the ten countries with the largest (average) beef and buffalo meat consumption. Out of the four countries with mean reversion (the Netherlands, New Zealand, Israel, and Hungary), only Hungary is among the ten countries with the smallest (average) beef and buffalo meat consumption.

The result is partially consistent with the suggestion in Solarin et al. (2025) that more persistent series are more volatile and more mean reverting series are less volatile. Japan and Poland (which are among the four countries with the most persistent beef and buffalo meat consumption series), are among the ten countries with the largest beef and buffalo meat consumption coefficient of variation, which is an indicator of volatility. Out of the four countries with mean reversion, only New Zealand is among the ten countries with the smallest beef and buffalo meat consumption coefficient of variation.

The dominant evidence for persistence of the beef and buffalo meat consumption is attributable to the persistence of the determinants of

Table 4

Estimated coefficients in an I(d) model with a linear time trend. Original data.

Country	α (t-value)	β (t-value)	d (95% band)
Austria	18.501 (17.15)	—	0.88 (0.77, 1.05)
Australia	43.455 (7.53)	—	0.77 (0.60, 1.02)
Canada	36.549 (22.35)	—	1.10 (0.90, 1.47)
Chile	17.348 (9.96)	0.157 (2.55)	0.58 (0.44, 0.80) ^{MR}
Colombia	20.006 (17.37)	—	0.96 (0.62, 1.55)
Costa Rica	17.338 (9.51)	—	0.62 (0.50, 0.79) ^{MR}
Denmark	16.507 (9.45)	—	0.97 (0.79, 1.24)
Finland	10.158 (20.67)	—	0.78 (0.64, 0.98) ^{MR}
France	28.241 (26.25)	—	0.92 (0.74, 1.43)
Germany	19.923 (26.53)	—	1.12 (1.01, 1.27)
Greece	7.282 (2.93)	—	0.71 (0.55, 0.94) ^{MR}
Hungary	16.549 (12.25)	-0.266 (-6.37)	0.50 (0.32, 0.76) ^{MR}
Iceland	11.759 (9.45)	—	0.65 (0.49, 0.91) ^{MR}
Ireland	16.683 (6.23)	—	0.78 (0.61, 1.02)
Israel	11.742 (5.83)	0.315 (5.46)	0.43 (0.33, 0.58) ^{MR}
Italy	14.672 (13.36)	—	1.06 (0.94, 1.23)
Japan	1.455 (3.52)	—	1.17 (1.02, 1.40)
Korea	-0.049 (-0.05)	0.308 (7.55)	0.68 (0.54, 0.86) ^{MR}
Mexico	9.052 (10.99)	—	0.97 (0.80, 1.25)
Netherlands	21.595 (28.36)	-0.090 (-4.44)	0.28 (0.09, 0.56) ^{MR}
New Zealand	58.023 (12.19)	-0.655 (-5.16)	0.29 (0.14, 0.51) ^{MR}
Norway	15.320 (18.93)	—	0.85 (0.71, 1.08)
Poland	9.108 (6.66)	—	1.11 (0.96, 1.39)
Portugal	6.070 (6.18)	0.248 (4.01)	0.80 (0.59, 1.09)
Spain	5.947 (9.10)	—	1.02 (0.85, 1.23)
Sweden	19.594 (20.29)	—	0.86 (0.74, 1.05)
Switzerland	24.272 (25.56)	-0.091 (-1.67)	0.79 (0.67, 0.97) ^{MR}
Turkey	3.441 (3.00)	0.225 (2.07)	0.92 (0.78, 1.11)
United Kingdom	25.132 (22.72)	-0.123 (-2.25)	0.72 (0.53, 0.97) ^{MR}
United States	42.279 (27.96)	—	1.13 (0.96, 1.39)

MR indicates evidence of mean reversion at the 95% significant level.

Table 5

Estimated coefficients in an I(d) model with a linear time trend. Logged data.

Country	α (t-value)	β (t-value)	d (95% band)
Austria	2.9204 (53.83)	—	0.87 (0.76, 1.04)
Australia	3.867 (35.47)	-0.0079 (-1.93)	0.61 (0.45, 0.82) ^{MR}
Canada	3.603 (83.48)	—	1.00 (0.84, 1.26)
Chile	2.838 (31.59)	0.0072 (2.53)	0.51 (0.36, 0.75) ^{MR}
Colombia	2.994 (48.34)	—	0.99 (0.66, 1.55)
Costa Rica	2.884 (26.33)	—	0.62 (0.50, 0.80) ^{MR}
Denmark	2.799 (28.08)	—	0.94 (0.75, 1.25)
Finland	2.896 (67.37)	—	0.78 (0.64, 0.98) ^{MR}
France	3.340 (91.08)	—	0.92 (0.75, 1.39)
Germany	2.996 (60.28)	—	1.04 (0.94, 1.18)
Greece	1.642 (12.51)	—	0.97 (0.79, 1.19)
Hungary	3.069 (24.29)	-0.0226 (-4.54)	0.63 (0.47, 0.88) ^{MR}
Iceland	2.456 (22.48)	—	0.60 (0.45, 0.83) ^{MR}
Ireland	2.814 (24.84)	—	0.79 (0.61, 1.03)
Israel	2.533 (25.65)	0.0148 (5.52)	0.35 (0.23, 0.53) ^{MR}
Italy	2.683 (52.70)	—	1.09 (0.97, 1.27)
Japan	0.388 (4.66)	—	1.21 (1.00, 1.61)
Korea	-0.228 (-1.57)	0.0539 (8.12)	0.69 (0.55, 0.91) ^{MR}
Mexico	2.195 (34.30)	—	1.00 (0.82, 1.33)
Netherlands	3.076 (76.91)	-0.0048 (-4.57)	0.28 (0.09, 0.55) ^{MR}
New Zealand	4.143 (41.89)	-0.0192 (-7.36)	0.23 (0.09, 0.43) ^{MR}
Norway	2.727 (58.33)	—	0.85 (0.70, 1.08)
Poland	2.458 (5.85)	-0.0539 (-2.83)	0.77 (0.64, 0.98) ^{MR}
Portugal	1.816 (23.36)	0.0202 (-2.23)	0.90 (0.74, 1.13)
Spain	1.771 (30.25)	—	1.09 (0.92, 1.31)
Sweden	2.974 (59.31)	—	0.87 (0.74, 1.07)
Switzerland	3.192 (79.59)	-0.0042 (-1.82)	0.77 (0.65, 0.94) ^{MR}
Turkey	1.263 (7.15)	0.0244 (2.26)	0.79 (0.64, 1.00)
United Kingdom	3.225 (58.14)	-0.0058 (-2.00)	0.74 (0.57, 0.97) ^{MR}
United States	3.744 (119.31)	—	1.13 (0.97, 1.36)

MR indicates evidence of mean reversion at the 95% significant level.

beef and buffalo meat consumption. Among the major determinants of beef and buffalo meat consumption are the prices of beef and buffalo meat and the general income level (Baruselli et al., 2025). In the traditional supply-demand model, the price of a commodity is the most

important determinant of the demand for such commodity. Income is the major determinant of demand for normal goods after their price (Karahan and Ozkan (2013). and Caporale et al. (2025) have shown that income is a persistent series, while Gil-Alana and Font de Villanueva (2022) has provided evidence that food prices (including beef and buffalo prices) are also a persistent series. According to Smyth and Narayan (2015), a regressand series tend to absorb the persistence of the independent variables affecting it. It can be seen that some countries produce persistence results, despite following different trends. Thus, some of the fractional integration estimates may be incidental.

The manuscript identifies Japan and Germany as highly persistent cases. A probable rationale for the result of Japan is due to the volatility of the series in this country. According to Hsu et al. (2008), highly persistent series tend to have high volatility. Based on the information conveyed in Table 1, Japan has one of the biggest coefficients of variation, which is a measure of volatility. Relative to many of the OECD countries, beef and buffalo meat consumption in Germany appears to be more sensitive to its determinants. According to Mata et al. (2023), driven by greater environmental awareness and higher dietary shifts toward vegetarianism, Germany has undergone a quicker decrease in beef and buffalo meat consumption than many other OECD countries.

6. Conclusions

Beef and buffalo meat are regarded as key providers of protein, and their levels of consumption are associated with different health benefits, as they provide critical nutrients such as iron, zinc, and vitamin B12. Nonetheless, too much consumption of beef and buffalo meat by humans may increase the chances of people contracting chronic illnesses. Besides, the consumption of beef and buffalo meat has a significant environmental impact. Hence, there is a need to reduce beef and buffalo meat consumption. In order to check whether short-term or long-term policies would be more appropriate in the pursuit of beef and buffalo meat consumption reduction, we have investigated the time series patterns of beef and buffalo meat in a group of 30 OECD countries by using fractional integration methods

This study adopts two complementary empirical approaches: a conventional autoregressive model of order one (AR(1)) and a fractional integration framework. Both techniques are applied to the original and the logarithmically transformed data to ensure robustness of the results. The AR(1) estimates reveal that most series exhibit high autoregressive coefficients, generally above 0.5 and often close to unity, indicating substantial temporal dependence. The results also show a clear geographical heterogeneity in the direction of the time trend: sixteen countries display a statistically significant negative trend—most notably Australia and New Zealand—while twelve show a positive one. The strongest persistence is found in Japan, Germany, Italy, and Poland, suggesting that consumption shocks in these markets tend to have long-lasting effects.

The fractional integration results provide strong support for the preceding analysis. The significantly positive estimates of the differencing parameter (d) reject the short-memory hypothesis and underline a substantial degree of persistence in many countries. Nations such as Germany, Japan, Spain, Italy, Canada, the United States, and Poland show d values close to or above one, suggesting enduring or even nonstationary behavior. Conversely, evidence of mean reversion in countries like the Netherlands, New Zealand, Israel, and Hungary indicates a faster dissipation of shocks. The matching estimates for Canada–Mexico and Spain–Italy highlight the potential influence of regional and structural similarities. In North America, strong trade linkages and common market exposure may account for these dynamics, while in Southern Europe, shared dietary habits and gradual adaptation to alternative protein sources appear to be relevant explanatory factors. Strong trade linkages and a common market synchronize the consumption patterns among North American countries (Azcona, 2022), which might be responsible for the similarity in their persistence in beef

and buffalo meat consumption. The Southern European countries have similar dietary habits which are profoundly influenced by the Mediterranean practices. These traditions include a greater intake of fish (as a result of long coastlines in many of these countries) at the expense of red meat consumption (Carballo-Casla et al., 2024).

Overall, both methodologies converge on the conclusion that beef and buffalo meat consumption in most OECD countries displays a high degree of persistence. This inertia probably reflects structural features of food demand, such as deeply rooted dietary preferences, relatively stable supply chains, and limited short-run price elasticity. The results imply the presence of hysteresis in beef and buffalo meat consumption. As such, any shock to the series is likely to have a permanent impact on future consumption pattern if interventions are not introduced. From a policy perspective, these findings imply that long term policies are more appropriate with regard to adequately achieving the desired level of beef and buffalo meat consumption. Besides, any attempts to reduce red meat consumption—whether for health, environmental, or sustainability reasons, are likely to have slow and gradual effects. The strong persistence of consumption habits poses a significant challenge to achieving rapid dietary transitions toward more sustainable and low-carbon food systems within the OECD. These findings are consistent with evidence showing that dietary habits around meat consumption are deeply rooted and resistant to short-term change.

The mean reversion of beef and buffalo meat consumption observed in a few nations implies that any shock to the series is likely to have a temporary impact on future consumption pattern in these countries. Authorities should not initiate excessive policies in the course of reducing beef and buffalo meat consumption. Moreover, the introduction of extreme measures, when beef and buffalo meat consumption briefly departs from the envisioned targets, should be dissuaded. Conversely, rolling short term measures can be more efficient in achieving the desired beef and buffalo meat consumption level. Short term measures include imposition of higher value-added tax on beef and buffalo meat consumption, removal of all non-essential subsidies on red meat, increasing subsidies on alternatives to red meat such as fish, and point-of-purchase labeling of red meat to reduce beef and buffalo meat consumption.

Subsequent papers could extend the present research from several angles. The persistence of beef and buffalo meat consumption in other regions or economic clusters could be examined in future studies. The persistence of sheep and goat consumption (and the consumption of other forms of red meat) can also be examined in order to gain a comprehensive understanding of the persistence of red meat consumption. Future papers can also focus on assessing beef and buffalo meat consumption convergence. The presence of convergence of beef and buffalo meat consumption is an indication of the need to use mutual policies to realize the optimal level of beef and buffalo meat consumption. While persistence is linked to determinants such as income and price, the paper does not empirically test these relationships within the presented models. A use of a multivariate framework to examine the relationship could be undertaken by future papers. Also, the use of panel data methods to control for unobserved cross-country heterogeneity when assessing convergence, or the integration of demographic variables into persistence models, would provide clearer pathways for subsequent studies. Finally, the possibility of unaccounted breaks can inflate fractional integration estimates (Diebold & Inoue, 2001), and this is another limitation of the present work. There exist procedures for testing structural breaks in the context of fractional differentiation (e.g. Gil-Alana, 2008.) and this will be investigated with the present data in future works.

CRediT authorship contribution statement

Gil-Alana Luis Alberiko: Formal analysis, Funding acquisition, Methodology, Project administration, Software, Writing – original draft.
González-Blanch María: Formal analysis, Funding acquisition,

Resources, Writing – original draft. **Carmen Lafuente:** Data curation, Formal analysis, Methodology, Visualization, Writing – original draft.
Solarin Sakiru: Data curation, Formal analysis, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

There is no conflict of interest with the publication of the present manuscript.

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