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Cheers to anxiety: Granger causality insights on alcohol consumption patterns across 13 South American countries

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Abstract

Background The relationship between alcohol consumption and mental health is complex; drinking may exacerbate anxiety, and in turn, anxiety can lead to excessive drinking. This study explores the relationship between alcohol consumption patterns including wine, beer, and spirits, and anxiety prevalence in selected 13 South American nations.

Methods This study utilises secondary data spanning 29 years from 1991 to 2019 obtained from the Our World in Data database. It investigates the causal link between the prevalence of anxiety and alcohol consumption in the selected countries using the Granger causality test.

Results Anxiety was found to have a unidirectional effect on wine and beer consumption in Chile, Suriname, Uruguay, and Trinidad and Tobago. Additionally, drinking alcohol consumption appears to impact anxiety levels in Brazil. Argentina demonstrates a bidirectional relationship between anxiety and all three types of alcohol consumption, with similar patterns observed in Brazil (wine and beer), Chile (spirits), and Paraguay (spirits).

Conclusion No significant causal relationships for alcohol consumption patterns were found in other nations. The identified Granger causal links follow four distinct directions in this study. These findings provide valuable insights for policymakers, governments, and international investors for informed decision-making regarding regulation and policy tools.

Keywords Alcohol consumption, Anxiety disorder, Anxiety prevalence, Granger causality, South American countries

Introduction

In the fields of behavioural science and public health, the relationship between alcohol consumption and anxiety has garnered significant attention due to their intertwined nature [1, 2]. This study aims to explore the complex correlations between these factors, particularly in South American communities where alcohol

consumption including wine, beer, and spirits. Alcohol is a drug extensively used worldwide [3]. Its effects on people can range from social and recreational usage to dependency and addiction [4, 5]. Alcohol consumption is shaped by factors such as social contexts, psychological states, cultural norms, and coping strategies. In contrast, anxiety, a common mental illness, disrupts daily functioning through excessive and persistent worry [6]. Anxiety's prevalence threatens both health and has significant socioeconomic impacts, with causes rooted in genetic predisposition, environmental conditions, and personal experiences [7].

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Understanding how lifestyle factors such as alcohol consumption impact anxiety symptoms is crucial [6, 8]. While alcohol is an acute anxiolytic, its long-term use can exacerbate anxiety [9], particularly during withdrawal. The type of alcohol wine, beer, or spirits may have varying effects on mental health due to differences in consumption patterns and social contexts [10]. Individuals with anxiety may use alcohol to self-medicate, potentially leading to increased consumption and dependency [11, 12]. This cycle of alcohol consumption and anxiety can lead to increased dependence [2, 13], where alcohol abuse exacerbates anxiety symptoms. Understanding this complex relationship is crucial for developing effective intervention strategies [14]. Creating successful intervention techniques requires an understanding of this complex relationship.

South America's diverse cultural, social, and economic landscape provides a unique backdrop. Previous research highlights the high prevalence of anxiety in this region, coupled with distinct alcohol consumption patterns [15]. Adapting public health initiatives to the cultural and contextual environment is crucial, particularly in South America, where anxiety is most prevalent. Wine, in moderation, is often associated with specific dietary habits in some South American areas and is proposed to have distinct health benefits [16]. Beer's psychological effects in North America are influenced by its informal consumption settings [17]. Spirits are the drink of choice in some areas of South America due to their higher alcohol content [18] yet, these regions may have differing binge drinking habits and alcohol-related problems. South America was chosen for this study due to its rapidly increasing anxiety rates, which have surpassed other continents in recent decades. The region's socio-economic challenges, such as economic instability, high unemployment, and political unrest, contribute to heightened anxiety levels [16]. This study explores how these factors interact with alcohol consumption patterns, offering critical insights into the mental health dynamics in a region facing significant stressors and providing a valuable understanding of the relationship between anxiety and alcohol consumption.

This study explores the relationship between anxiety prevalence and alcohol consumption, specifically wine, beer, and spirits in South America. Using Granger causality analysis across all South American countries over an extended period, the research offers comprehensive insights into the complex dynamics between anxiety and alcohol use. It also considers factors like economic depression and domestic violence, providing guidance for regional health policies and contributing to global discussions on anxiety and alcohol misuse. The remaining sections of this paper are organized as follows:

Sect. "Results" reviews the literature on the research problem. Sect. "Discussion" outlines the study's data and methodology. Sect. "Conclusion and policy implications" presents the empirical results, followed by a detailed discussion in Sect. 5. Finally, Sect. 6 concludes with policy implications.

Literature review

The relationship between alcohol consumption and anxiety is complex, supported by evidence of a reciprocal relationship [2, 19]. Alcohol, a widely used psychoactive drug, has the potential to cause dependency and is linked to 5% of the global burden of illness due to misuse. Overindulgence in alcohol is a leading cause of disability worldwide, with around 32.5% of the global population consuming alcohol [20]. Not only that but also the overall consumption of alcoholic beverages is heavily influenced by a wide range of contextual factors such as cultural norms, drinking patterns, income levels, education, urbanisation, aging, immigration, and economic conditions, as supported by the literature [21]. These factors are recognised as the socio-economic and cultural determinants which plays a crucial role in shaping drinking behaviours and their associated mental health outcomes.

Binge drinking affects approximately 18.4% of adults, and 5.1% have an alcohol use disorder, with variations across countries [22]. Alcoholic drinks fall into three main categories: wine, beer, and spirits, with spirits comprising about half of global alcohol consumption, followed by beer and wine [23].

Consumption patterns vary by region; in South America, wine is particularly popular, largely due to cultural influences such as the Mediterranean lifestyle [23, 24]. Alcohol consumption is a significant public health issue in Latin America [7], with countries like Peru, Paraguay, Brazil, Chile, Argentina, and Uruguay having particularly high per capita consumption rates [20, 25]. Research indicates that social alienation, educational inequalities, and economic instability significantly contribute to the global prevalence of anxiety and depression [26], with anxiety rates increasing by 25% since 2019 [27]. Stress-reduction theory suggests alcohol acts as an acute anxiolytic [28], but research shows its effectiveness in alleviating anxiety is inconsistent [14, 29]. Yet, individuals may consume alcohol as a means of coping with stress and anxiety. According to this theory, alcohol can be used as a self-medication strategy to alleviate symptoms of anxiety, particularly in the short term. However, it is also well-documented that this coping mechanism can lead to problematic consumption or Alcohol Use Disorders (AUDs) over time, creating a cycle where alcohol consumption both alleviates and exacerbates anxiety. But

this elevated anxiety levels are strongly correlated with alcohol withdrawal [30]. Epidemiological studies highlight significant comorbidities between alcohol use and anxiety disorders, with the relationship varying by anxiety type [31]. Alcohol use disorders often follow anxiety disorders like social phobia and agoraphobia [32, 33]. Diagnosing these conditions is challenging in active alcohol users, as symptoms may mimic alcohol withdrawal [6, 34].

In therapeutic settings, it is challenging to establish a unidirectional causal relationship between alcohol use and anxiety [35]. Alcohol can create a cycle of worsening anxiety and alcohol dependence, intensifying both disorders [9, 36]. Despite alcohol's short-term calming effects, its long-term use often amplifies anxiety due to withdrawal-induced autonomic hyperexcitability and the social and professional disruptions associated with excessive drinking [34, 37].

Argentina, a middle-income nation with high alcohol consumption rates, faces significant disparities in alcohol use among socioeconomic groups. Argentina, alongside Chile, is a major wine producer in the Southern Hemisphere, with wine production being a key revenue source in Western and Northern Argentina [38, 39]. Despite modest tax rates, intense pressure from the wine and beer industries has limited regulation, focusing efforts on traffic safety and sales restrictions for minors, rather than broader health promotion [38, 40].

In South America, health concerns are significant, with 15.4% of Argentinians experiencing anxiety or mood disorders in 2020 [40]. In Brazil, the average alcohol consumption was 7.8 L per person in 2016, with men drinking more than women [20, 41]. A 2019 Brazilian survey revealed that 73% of adults were non-drinkers, with heavy drinking more common among men [42]. Anxiety rates in Brazil reached 44% by 2020, higher than pre-pandemic levels [43].

Brazilian research shows an anxiety prevalence of 81.9%, higher than in other South American nations, with 40.4% to 52.6% experiencing related symptoms [17, 41, 44]. In Bolivia, drug misuse accounts for 30% of hospital admissions, and 47% of women report experiencing spousal violence [15, 19, 45]. These scholars concluded that Bolivia has a high rate of intimate partner violence.

Chile imposes a 20.5% ad valorem tax on wines, beers, and sparkling wines, and 31.5% on distilled spirits [35]. Strategies like minimum pricing and banning "happy hours" target youth, who are most vulnerable to alcohol-related harm [24]. Epidemiological research shows 16.5% of Chileans experience psychological problems, with anxiety and depression prevalent among university students [35, 46]. Extended isolation and social alienation have exacerbated mental health

issues, creating a complex relationship between anxiety and alcohol consumption [47].

In Suriname, spirits and beer dominate alcohol consumption at 49% and 45%, respectively, while wine is only 3% [48]. Comorbid depression affects up to 90% of those with anxiety, with women at higher risk [49, 50]. Depression in women is linked to socioeconomic challenges [51].

Peru has experienced high levels of anxiety, depression, and stress, particularly during the COVID-19 pandemic, with rates higher than in any other Latin American country [52]. Social isolation, unemployment, and low educational attainment are significant contributors to these mental health issues [15, 53].

Uruguay, often overlooked in the wine industry, has a 500-year history of winemaking [54]. Despite political and economic challenges, local winegrowers have preserved this heritage [55]. Depression and anxiety, common during adolescence, frequently coexist with alcohol issues, with a 20% prevalence of problematic alcohol use [56].

Anxiety and sadness are increasing, with limited access to mental health services, making the crisis in Venezuela severe. The World Federation for Mental Health declared a mental health crisis due to drug shortages, worsening previously controlled disorders [53]. While nutrition data in Venezuela is scarce, multifaceted public health challenges, including the complex relationship between alcohol consumption and anxiety, persist across South America [15, 53].

This study uniquely employs Granger causality analysis to examine the relationship between alcohol consumption and anxiety across South America over an extended period, offering a comparative perspective across countries. The findings highlight the critical role of socioeconomic factors in anxiety prevalence and emphasize the need for targeted strategies in South American nations. The study supports the development of focused programs to reduce alcohol consumption and address mental health issues, contributing to the global discourse on the complex relationship between alcohol use and anxiety amidst changing legislative and economic contexts.

Overall, this research fills a gap in the literature by offering an analytical framework that highlights the interplay between alcohol consumption and anxiety in South America, with implications for policy-making and public health initiatives.

Data and methodology

This study probed into four major variables: anxiety prevalence, wine, beer, and spirits consumption, applying two distinctive measuring techniques. For the purpose of measuring wine, beer, and spirits consumption,

the metric of litres of pure alcohol consumed per capita was utilised, whilst the metric of anxiety prevalence per 100,000 people was employed to assess the anxiety prevalence. Our World in Data database and the WHO website are the two secondary sources used for data collection (Table 1).

S1 Appendix contains the dataset utilised for the investigation. This study focused on 13 countries categorised as part of the South American continent. For all four variables considered in this study, yearly data covering the period from 1991 to 2019 were extracted from the said database. The dataset utilised comprised 377 observations in total, offering a robust basis for the research study. The S2 Appendix, which is part of the supplemental materials, has the dataset’s complete descriptive statistics attached.

The study’s approach is predicated on Panel Granger causality analysis. This section explores the Granger causality within a panel data framework. Granger causality analysis is a statistical technique used to see if the temporal ordering of two variables may be used to predict one another. Panel data, which mixes time-series and cross-sectional data, is used in this study to investigate causal linkages across several entities and time periods. To ascertain if the previous values of one variable can aid in the prediction of the future values of another variable, Granger causality analysis is applied in this study. The basic idea represents that, if variable X is a Granger-cause of variable Y, then past values of X ought to have more predictive value for Y than just past values of Y.

For each pair of variables of interest in our study, namely, anxiety prevalence and alcohol consumption, including wine, beer, and spirits; runs the Granger causality test. This entails taking the panel data structure into consideration while evaluating time-series regression models. Finding out if one variable’s lag values

significantly contribute to the explanation of the other variable’s variance is the main focus here.

The Granger causality test assesses how the variables are causal. The formulas for Granger causality are as follows:

$$AD_{i,t} = C_0 + \sum \alpha_i AD_{t-1} + \sum \beta_i WC_{t-1} + \varepsilon_t \quad (1)$$

$$WC_{i,t} = C_0 + \sum \gamma_i WC_{t-1} + \sum \delta_i AD_{t-1} + \varepsilon_t \quad (2)$$

$$AD_{i,t} = C_0 + \sum \delta_i AD_{t-1} + \sum \pi_i BC_{t-1} + \varepsilon_t \quad (3)$$

$$BC_{i,t} = C_0 + \sum \rho_i BC_{t-1} + \sum \sigma_i AD_{t-1} + \varepsilon_t \quad (4)$$

$$AD_{i,t} = C_0 + \sum \varphi_i AD_{t-1} + \sum \omega_i SC_{t-1} + \varepsilon_t \quad (5)$$

$$SC_{i,t} = C_0 + \sum \theta_i SC_{t-1} + \sum \tau_i AD_{t-1} + \varepsilon_t \quad (6)$$

If the sum of estimated coefficients on lagged wine consumption (WC) is statistically different from zero and the sum of estimated coefficients on lagged anxiety disease prevalence (AD) is not statistically different from zero (Eq. (1)), then a unidirectional causal relationship exists between the two variables. Equation (2) outlines the inverse link between AD and WC if the opposite findings are proven. Two variables can be shown to impact one another in a bidirectional causal relationship if their coefficients are statistically different from zero.

If the sum of estimated coefficients on lagged beer consumption (BC) is statistically different from zero and the sum of estimated coefficients on lagged anxiety disease prevalence (AD) is not statistically different from zero (Eq. (3)), then a unidirectional causal relationship exists between the two variables. Equation (4) outlines the

Table 1 Data sources

Variable	Measurement unit	Source
Anxiety	Anxiety disease prevalence	Our World in Data (2024) https://ourworldindata.org/grapher/number-with-anxiety-disorders-country
Wine Consumption	Litres of pure alcohol consumed per capita	World Health Organization (2024) https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption
Beer Consumption	Litres of pure alcohol consumed per capita	World Health Organization (2024) https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption
Spirit Consumption	Litres of pure alcohol consumed per capita	World Health Organization (2024) https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/levels-of-consumption

Source: Author’s compilation from Our World in Data and the WHO

inverse link between AD and BC if the opposite findings are proven. Two variables can be shown to impact one another in a bidirectional causal relationship if their coefficients are statistically different from zero.

If the sum of estimated coefficients on lagged spirit consumption (SC) is statistically different from zero and the sum of estimated coefficients on lagged anxiety disease prevalence (AD) is not statistically different from zero (Eq. (5)), then a unidirectional causal relationship exists between the two variables. Equation (6) outlines the inverse link between AD and SC in the event that the opposite findings are proven. Two variables can be shown to impact one another in a bidirectional causal relationship if their coefficients are statistically different from zero.

Results

This section reveals the descriptive statistics of the variables taken into consideration: anxiety prevalence and alcohol consumption, including wine, beer, and spirits, followed by a thorough examination and discussion of the Granger-causality test results.

The prevalence of anxiety over time in various categories is depicted in Fig. 1. The categories in this instance are continents: Africa, Asia, Europe, North America, Oceania, and South America. Over the course of the 29-year period, anxiety prevalence has been on the rise in both Europe and South America. In Europe, instances of anxiety per 100,000 people began to rise slightly beyond 4,500 in 1991 and continued to rise gradually until they fell barely short of 5,500 cases in 2019. Though the curve ends somewhat lower than that of Europe, South America begins at the same point. The somewhat

flatter lines for Asia and Africa indicate a steadier incidence of anxiety. Over the above-mentioned period, Africa has shown a very modest increased tendency but has remained below 4,000 instances, whereas Asia has remained slightly above 3,500 cases. Concerning anxiety prevalence, the graph permits comparisons between continents and according to the data supplied reveal that Asia and Africa have the lowest prevalence by 2019 while South America and Europe have the highest prevalence.

The higher frequency of anxiety across the continent of South America is likely attributed to several instabilities such as economic instability, unemployment, and poverty. Furthermore, those who live in regions that are experiencing political unrest or continuous violence are susceptible to have greater levels for excessive worrying. However, underdiagnosis in areas with better access to mental health care, expectations related to performance, appearance, and social status, and genetic predispositions to anxiety that differ among populations can contribute to higher rates of anxiety prevalence.

The prevalence of anxiety over time in South American and European continents is illustrated in Fig. 2. The regression study comparing the prevalence of anxiety in South America and Europe, as shown by the corresponding equations; $Y=28.305x+4576$ with an R^2 of 0.8985 and $Y=7.5032x+4865.2$ with an R^2 of 0.8257.

The comparison of the two equations in the Fig. 2. show that South America has a more pronounced rising tendency, which is higher than that of Europe's trend. This numerical difference in trends depicted in Fig. 2. suggests that anxiety prevalence is rising four times faster in South America than that in Europe. Also, the projected prevalence rate of anxiety would have been 4,576 instances per

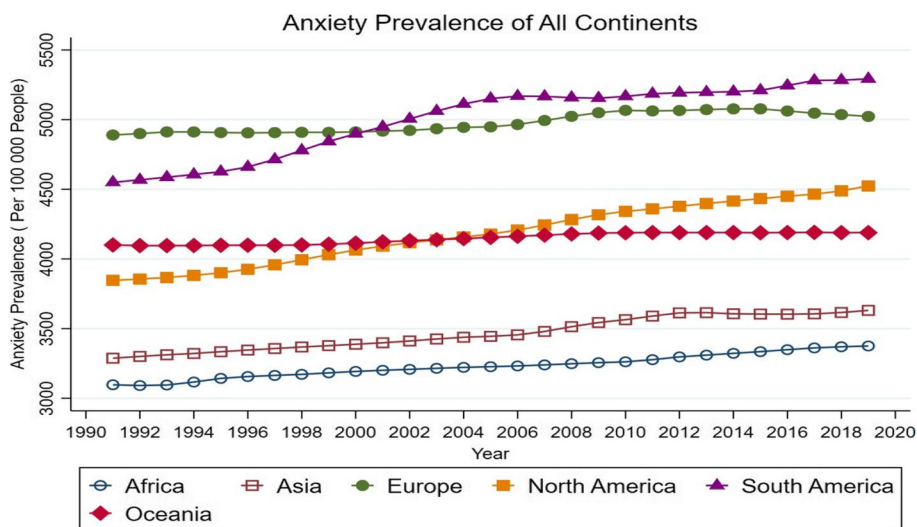


Fig. 1 Anxiety prevalence of all continents. Source: Authors' illustration based on STATA software

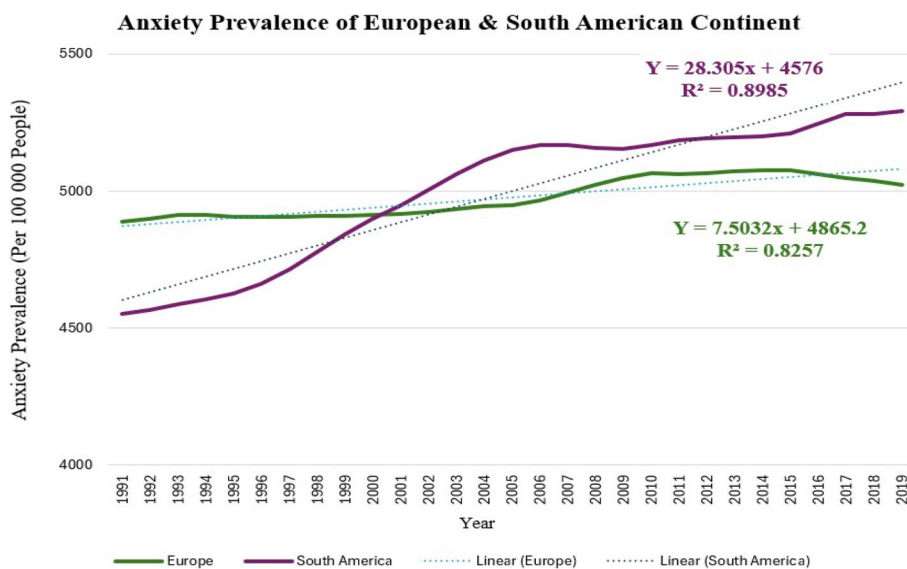


Fig. 2 Anxiety prevalence in European and South American continents. Source: Authors' illustration based on Excel

100,000 people at the start of the time series in the South American continent. Comparatively, Europe had a higher estimated baseline prevalence of anxiety at the beginning of the investigation, with 4,865.2 instances per 100,000 people. By interpreting these instances, South America had a lower prevalence of anxiety at first, whereas Europe had a greater rate. Additionally, a better fit for the linear regression model is shown by a higher R^2 value for South America, indicating that the observed trend is more representative of the underlying data for this region.

A graphic analysis of the trend lines shows that from about 2009, South America has a higher incidence of anxiety than Europe, and that advantage continues for the duration of the dataset, which covers the years 1991 to 2019. Thus, two statistical measures, the rising tendency and the R^2 value offer a strong basis for the claim that anxiety prevalence has increased more sharply in South America than in Europe during the course of the study period. Overall, this explains the purpose to conduct this study and analyses the Granger-causal linkages between anxiety and various alcohol consumption patterns in South American continent.

Given these conditions, South America presents a critical and urgent context for studying the relationship between anxiety and alcohol consumption patterns. The region's rising anxiety prevalence, combined with the diverse socio-economic challenges faced by its population, makes it an ideal setting for exploring how different types of alcohol consumption may be linked to mental health outcomes. Understanding these dynamics in South America could provide valuable insights that may

be applicable to other regions experiencing similar socio-economic stressors and mental health challenges.

According to the S2 Appendix, Paraguay has the highest rate of anxiety, whilst Suriname has the lowest. Wine consumption is the greatest in Uruguay and the lowest in Guyana when it comes to alcohol consumption. In Venezuela, the most beer is consumed, whereas in Ecuador, the least. The highest consumption of spirits is found in Guyana, while the lowest consumption is found in Bolivia. The incidence of anxiety and patterns of alcohol consumption vary significantly between nations, as these figures show.

S3 Appendix demonstrates wine consumption trends in South American countries from 1991 to 2019. The Argentina's wine consumption peaked in 1991 at almost 9 L per capita. From then on, it slumped until the mid-1990s, stabilising briefly before progressively declining once again to a level of about 4 L per capita. Chile's per capita consumption begins at about 2.5 L and rises gradually until the early 2000s, when it peaks at about 4 L. It then shows a marginal drop, which is followed by a plateau. The expansion and globalisation of the Chilean wine business may be reflected in this surge and subsequent stabilisation. Uruguay's per capita consumption gradually increased from less than 3 L in 1991 to a peak of about 3.5 L in the mid-2000s, after which it declined. The seemingly quite flat and constant trend line for wine consumption per capita in Paraguay shows continuous low levels of wine consumption during the 29-year period. The circled line at the bottom of the statistics may indicate that wine is not a popular alcoholic beverage among

Paraguayans or that there hasn't been much of a shift in wine consumption over time.

S4 Appendix depicts beer consumption trends in several South American countries during the said period. The Venezuela's consumption pattern shows a sharp decline after 2010 and a rise in consumption up to the late 2000s. The well-documented economic crisis in the nation, which considerably affected purchasing power and total consumption, is probably to blame for this fall. Colombia shows a steady rise in consumption that picks up speed in the late 2000s and continues to do so, whereas Suriname shows a relatively flat trend that indicates modest and stable consumption levels. A moderate increasing trend is seen in Paraguay, with growth becoming more pronounced in the latter half of the 2000s.

S5 Appendix indicates spirit consumption trends in several South American countries from 1991 to 2019. Guyana's consumption of spirits varies significantly. A high in 2004 after a rise in the early 2000s, and then a plunge around in 2005. These variations may be caused by alterations in social customs or governmental regulations, as well as economic variables like inflation or recession. Paraguay's consumption of spirits exhibits notable fluctuations. Following a spike in the early 2000s, the curve is essentially flat with just minor variations, suggesting a steady rate of spirit consumption.

The other South American nations related to wine, beer, and spirits, continue to consume at lower and comparatively consistent levels. A multitude of reasons exist for this stability, including cultural preferences, financial limitations, and the availability of alternative alcoholic beverages that are more widely consumed in certain areas. Due to its persistently low usage in a number of nations, wine may not be the preferred alcoholic beverage. This might be for various historical, cultural, or economic reasons, all of which would require extensive research to properly comprehend.

Granger causality test

Through Granger causality methodology, our variables were tested as grants under three different procedures before Granger causality Wald test. First, through unit root test, second, lag-order selection criteria, and third, vector autoregression.

The Dickey-Fuller test is a statistical tool frequently used by researchers to determine whether or not a time series is stationary and has a unit root. The findings of the time-series unit root test for the anxiety prevalence per 100,000 people and the alcohol consumption patterns of wine, beer, and spirits in litres of pure alcohol consumed per capita; are reported in the S6 Appendix. Unit roots are a feature of several stochastic processes that can cause random walks and other erratic behaviour

over time. The fundamental idea of the test is to compare the alternative hypothesis-that the time series is stationary, i.e., shows mean-reverting behaviour and lacks a unit root-with the null hypothesis, indicating that a unit root is present. The time series may be impacted by a trend or its own lag values if the test is unable to reject the null hypothesis, which implies that the time series is non-stationary and may include a unit root.

The test statistic and the p -value are typically used to interpret the test result. The null hypothesis of a unit root existence is rejected if the p -value is less than a certain threshold (usually 0.05), indicating that the time series is stationary. Since many models need the series to be stationary, the Dickey-Fuller test is frequently used in econometrics and time series analysis to ensure that the data attributes are appropriate for additional statistical modelling.

First and foremost, selecting the appropriate number of lags is essential while conducting time series analysis, particularly when utilising models like vector autoregression. This procedure, known as lag sequence selection, is crucial as the number of delays can impact the model's accuracy and drawing inferences from it. Variance bias can be avoided by selecting too few lags, while overfitting and needless complexity can result from selecting too many delays.

A number of statistical parameters are frequently applied while choosing a delay order. Among the most used criteria is the Akaike Information Criterion. By punishing the inclusion of extra delays, it strikes a balance between the trade-off between model fit and model complexity. It determines which model with the fewest parameters best matches the data. The model with the lowest Akaike Information Criterion value is recommended. Schwarz Criterion, also known as the Bayesian Information Criterion, is a model parameter count penalty that is larger than that of the Akaike Information Criterion. It favours simplicity over complexity and tends to choose models with fewer delays than Akaike Information Criterion, even when the model fit is somewhat worse. Typically, the model chosen is the one with the lowest Bayesian Information Criterion value. The Hannan-Quinn Information Criterion. Further criteria that achieve equilibrium between model fit and complexity is Hannan-Quinn Information Criterion. The inclusion of extra parameters that are greater than Akaike Information Criterion but lower than Bayesian Information Criterion is penalised. Although it is uncommon, it can be a better substitute in situations when Akaike Information Criterion chooses too many delays and Bayesian Information Criterion chooses too few. Final Prediction Error evaluates the model's predictive accuracy and estimates the difference between the expected and actual

values. The model with the lowest Final Prediction Error is recommended.

The process of selecting the lag length that minimises the relevant criterion often includes fitting the model with various lag lengths. Although these factors may offer contradictory advice, in actuality, it is typical to consider many of these factors simultaneously when deciding on a delay sequence. In light of the available data and the phenomena under study, the selected lag time should also make theoretical sense.

The Vector autoregression model can be evaluated when the proper lag order has been determined. The process of estimating entails fitting the model to the time series data, regressing each variable on both its own and all other variables' lags. Ordinary Least Squares regression is usually used for every equation in the Vector autoregression system. In addition to serving as the foundation for testing Granger causality, which is based on the idea that if the first variable Granger-causes the second variable, past values of the first variable should contain information that helps predict the second variable above and beyond the information contained in past values of the second variable alone. The Vector autoregression model offers a framework for analysing the dynamic interrelationships among the multiple time series.

Granger causality is a statistical concept that is frequently applied in time series analysis and econometrics to evaluate the causal relationship between two variables. The technique named after Nobel laureate Clive Granger assists scientists in determining whether a given variable can influence or predict changes in another over an extended period of time.

First, a null hypothesis is put in, which postulates that the two variables have no causal link. The Granger causality test is then used to the data analysis. A causal relationship between two variables is suggested if the test findings reject the null hypothesis, meaning that changes in one variable may be linked to previous values of the other variable. The Granger causality test aids in determining the direction and degree of causal linkages between variables and is useful for predictive modelling and evidence-based policy choices across a number of academic disciplines. In conclusion, Granger causality is a main technique researcher use when determining the cause of a given variable. In this study, Granger causality has been used for the investigation of the inter-dependence structure of the underlying systems.

The results of the Granger causality test are presented in Table 2, examining the nexus between anxiety prevalence and alcohol consumption patterns in South American continent. Between the anxiety prevalence and wine consumption, a bi-directional causality relationship exists

in Argentina and Brazil. In Chile, Suriname, Trinidad and Tobago, and Uruguay a one-way causality relationship is found with a one-way right-directional causality relationship from anxiety to wine consumption. Therefore, anxiety increases wine consumption in the four countries mentioned above. Additionally, seven counties showed no causality relationship between anxiety and wine consumption.

Regarding the analysis of anxiety prevalence and beer consumption in the South American continent, bi-directional causality was observed in Argentina and Brazil. A one-way right-direction from anxiety to beer consumption was observed only in Chile. Other countries namely, Bolivia, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and Venezuela showed no Granger causality relationship between anxiety and beer consumption.

When observing the results between anxiety prevalence and spirit consumption in these countries in our dataset, only three countries, namely Argentina, Chile, and Paraguay show a bi-directional causal relationship. It is noteworthy that only Argentina showed a bidirectional relationship for all the three alcohol consumption patterns. A specific result was observed only for spirit consumption in Brazil, indicating a one-way left-direction Granger causality from spirit consumption to anxiety. Furthermore, the remaining nine countries show no clear causative relationship between anxiety and spirits. Finally, the summary showed that in over 50% of the South American continent, no Granger causal relationship exist between anxiety prevalence and the consumption of three categories of wine, beer, and spirits.

Discussion

The dominant focus of this study was the consumption of wine, beer, and spirits and determining the cause of anxiety. The findings can be regarded as a significant illustration of the South American continent. A bi-directional relationship between anxiety and all three types of alcohol consumption was observed only in Argentina. Only Brazil shows a bidirectional causal relationship between anxiety and the two alcoholic beverages, wine, and beer. Furthermore, Chile and Paraguay only show a bidirectional causal relationship between anxiety and spirit consumption. Argentina is showing exceptional results with its South American counterparts. A large epidemiological survey of the general population in Argentina found that, anxiety disorders were the most common mental health disorder with a lifetime prevalence of 16% [39]. Besides, Argentina, as a middle-income nation, has a high and harmful alcohol utilisation [19, 39]. Moreover, wine production is the biggest source of income in Western and Northern Argentina, and numerous economic

Table 2 Nexus between anxiety and alcohol consumption patterns in South American continent using Panel Granger causality test

Country	Anxiety - Wine		Anxiety - Beer		Anxiety - Spirit				
South America									
Argentina	dddAnxiety	↔	Wine	dddAnxiety	↔	dBeer	dddAnxiety	↔	dSpirit
	132.11***		24.883***	062.048***		69.454***	10.765**		31.993***
Bolivia	Anxiety	↔	dWine	Anxiety	↔	dBeer	Anxiety	↔	dSpirit
	.80021		7.2629	1.0963		1.3523	5.1589		.62687
Brazil	dddAnxiety	↔	Wine	dddAnxiety	↔	dBeer	dddAnxiety	←	dSpirit
	20.514***		10.467**	10.518**		10.8**	4.5447		32.369***
Chile	dddAnxiety	→	Wine	dddAnxiety	→	dBeer	dddAnxiety	↔	Spirit
	46.324***		1.7394	13.643**		3.3417	38.735***		12.031**
Colombia	ddAnxiety	↔	Wine	ddAnxiety	↔	Beer	ddAnxiety	↔	dSpirit
	2005		.02178	.55273		1.3388	.9598		.10262
Ecuador	ddAnxiety	↔	dWine	ddAnxiety	↔	dBeer	ddAnxiety	↔	dSpirit
	4.262		1.2043	3.9765		2.7562	.24307		.83755
Guyana	dAnxiety	↔	dWine	dAnxiety	↔	dBeer	dAnxiety	↔	dSpirit
	1.9066		.7517	.16521		.0342	.5055		.1031
Paraguay	dddAnxiety	↔	Wine	dddAnxiety	↔	dBeer	dddAnxiety	↔	dSpirit
	4.675		1.8042	3.2056		1.1222	13.885**		8.1077*
Peru	ddAnxiety	↔	dWine	dddAnxiety	↔	dBeer	ddAnxiety	↔	dSpirit
	1.2346		.62103	.12027		.21707	.86119		2.0517
Suriname	ddAnxiety	→	Wine	ddAnxiety	↔	dBeer	ddAnxiety	↔	Spirit
	11.246		.79428	2.0044		.00061	.32816		.44829
Trinidad and Tobago	dAnxiety	→	dWine	Anxiety	↔	dBeer	Anxiety	↔	Spirit
	6.7132**		3.2049	3.3824		0.721	0.109		0.911
Uruguay	dddAnxiety	→	dWine	dddAnxiety	↔	dBeer	dddAnxiety	↔	dSpirit
	23.369***		.59748	3.0151		4.4902	1.5659		8.4926**
Venezuela	dddAnxiety	↔	dWine	dddAnxiety	↔	dBeer	dddAnxiety	↔	dSpirit
	0.953		0.752	0.504		0.106	0.481		0.381

The characters → and ← represents one-way-right direction and one-way-left direction causal relationship, ↔ and ↔ represents a bi-directional, no causal relationship, respectively

dAnxiety First difference of anxiety, ddAnxiety Second difference of anxiety, dddAnxiety Third difference of anxiety, dWine First difference of wine, dBeer First difference of beer, dSpirit First difference of spirits. Source: Authors' compilation based on Granger causality Wald tests

* Denotes significant at the 10% level

** at the 5% level

*** at the 1% level

operators are involved in this exertion. In Argentina, wine and beer have historically been burdened at generally low tax rates, given the high prevalence of alcoholism among the Argentine youth populace [39, 43]. This may be due to lax control and low tax collection of alcoholic beverages, especially in Argentina [19]. These reasons affirm the high consumption of alcohol in Argentina and the resulting predominance of anxiety. In Argentina, a wine and beer-creating nation, the harmful use of alcohol among heavy drinkers has expanded during the period under study between 1991 to 2019. This is compelling evidence that alcohol consumption is prevalent, especially among the 18–24 age group, and that anxiety too is prevalent [39].

Only Brazil shows a bidirectional causal relationship between anxiety and the two alcoholic beverages, wine and beer. It is the country with the highest number of mental disorders in South America [7]. That is, a quarter of the adult Brazilian population has depressive symptoms, and a fifth of the Brazilian population has anxiety symptoms [20]. Depressive symptoms, anxiety symptoms, and negative life events were strong predictors of each other, providing evidence that hazardous

alcohol consumption significantly intensify anxiety in Brazil [41]. Also, the multi-modal factors that should be considered in bidirectional Granger causality analysis. Therefore, among Brazilian women, the highest prevalence of anxiety is found in middle-aged women [43], followed by older women and young women. This prevalence was almost twice that of men and found significant interaction effects between heavy drinking and age group and between heavy drinking and gender [44], leading the literature to analyse gender and age sub-groups. The results also provide evidence that anxiety patients are more likely to consume wine and beer in a bidirectional relationship. In Brazil, anxiety sufferers believe that alcohol acts as a self-medication, thereby reducing anxiety [20, 41]. Interestingly, this finding is in contrast with most prior research. Accordingly, moderate drinking in middle-aged women between 40–59 years, showed a reduction in current anxiety and depression compared to their nondrinking counterparts [53]. However, due to heavy drinking, young and middle-aged men had higher rates of current depression compared to their non-heavy drinking counterparts [26]. When examining the results, only Chile and

Paraguay showed a bidirectional causal relationship between anxiety and spirit consumption.

Furthermore, the findings observed only one path from anxiety to wine consumption and from beer consumption to anxiety in Chile. In Chile, a high-income country in South America, alcohol consumption has increased among young people [46, 47]. Suriname, Trinidad and Tobago, and Uruguay show one path from anxiety to wine consumption on the left. About 85% of depressed patients in Suriname also experience sizeable levels of anxiety [49]. The direction of Granger causality shows that people with Suriname anxiety disorder are more prone to drinking wine. Observations revealed that people with anxiety in Uruguay were more likely to consume wine than beer and spirits [46, 47]. The reverse of this scenario can be applied to countries such as Brazil, where spirit consumption increases anxiety symptoms.

As a result, the relationship between anxiety prevention and alcohol consumption is complicated. In contrast to the generated results through Granger causality Wald test, in terms of the South American content, there is no strong evidence that alcohol consumption affects the prevalence of anxiety disorders yet calls for a deeper analysis on age groups. Thus, countries such as Bolivia, Colombia, Ecuador, Guyana, Peru, and Venezuela have no causal relationship between anxiety and wine, beer, and spirits consumption. According to the facts of the literature mentioned earlier as influencing factors that are not directly related to alcohol consumption [50]. It is worrying that domestic violence is higher than normal in Latin America, including Bolivia [26]. This is confirmed by the fact that previous studies have explained that the rise in domestic violence has led to the development of anxiety disorders in countries like Bolivia, despite alcohol consumption [50, 51]. In the context of poverty, low social capital, social segregation, and other adversities that often occur in cities, a greater risk lies for mental disorders [36, 57, 58]. Guyana and Peru represent these reasons for the prevalence of anxiety. Furthermore, these issues of anxiety in general are situated within the broader context of the violence and structural barriers prevalent in contemporary Guyanese social life [51]. It can be linked to structural factors such as poverty, social inequality, and marginalisation that can put young people at greater risk for negative outcomes throughout their lives [27]. According to observations obtained in South America, especially in Paraguay, there is no relationship between wine consumption and beer consumption. According to World Bank data, Paraguay has the highest consumption of beer with 54% [25]. Beer consumption is said to have a direct or indirect effect on anxiety.

In addition, the World Bank has stated that poverty is the most common cause of mental illnesses such as anxiety

in low-income countries such as Paraguay [19]. Currently, there is no direct relationship between spirit consumption and beer consumption for the prevalence of anxiety in Suriname, Trinidad and Tobago and Uruguay. Unemployment, domestic work of women, and lack of safe environment for youth evidence suggest that financial deprivation exerts additional pressure on their mental well-being and amplifies the prevalence of anxiety [59, 60]. Alcohol consumption is common among Trinidadians with the prevalence of binge drinking at 22.6%-68.7% [59], despite no Granger causality relationship between beer and spirits in Trinidad and Tobago.

A Granger causality study investigated the relationship between anxiety and wine, beer, and spirit consumption, where alcohol consumption in South America was analysed as a risk factor for anxiety. Therefore, the insights provided by this study are useful for health workers as well as related policymakers.

Limitations

The researchers employed the Granger causality test to investigate whether historical patterns of alcohol consumption could predict future anxiety levels and vice versa. To ensure a broader contextual focus, the authors controlled macro-level factors such as economic status and cultural practices, rather than delving into micro-level details that may not be universally applicable across different countries.

Nonetheless, this approach has its limitations. While the Granger causality test can identify temporal relationships, it does not account for all possible underlying variables or the complex interactions between them. As a result, the findings may be influenced by factors not included in the model. Furthermore, while examining overall alcohol consumption could offer a more generalized understanding of the relationship between alcohol and anxiety, the researchers chose to focus on specific types of alcoholic beverages. This approach was intended to explore whether different types of alcohol exhibit distinct relationships with anxiety, thereby providing more targeted insights that could be useful for policy-making and public health interventions.

The limitations of this study suggest that international and political organizations might benefit from reflecting on how their policies have historically impacted alcohol consumption and anxiety prevalence. The study contributes to a broader understanding of emerging patterns and future trends related to this issue across South America. A potential extension of this research could involve examining Granger causality on a nation-by-nation basis within this context. Additionally, expanding the scope of this research to include gross domestic product as a

moderating factor under socioeconomic status could enhance the study's validity and generalizability in the future.

Conclusion and policy implications

This study provides fascinating insights into the socio-behavioural patterns that regulate the link between anxiety and alcohol consumption across South America, based on rigorous analysis. Particularly, Argentina and Brazil stand out as regions where anxiety and wine and beer consumption are positively correlated, highlighting a cycle in which one may worsen the other's presence. This reciprocal relationship raises the possibility of a complicated interaction between the general public's psychological health and alcohol consumption patterns.

Additionally, countries like Chile, Suriname, Trinidad and Tobago and Uruguay show a one-way causal relationship between wine consumption and anxiety, suggesting that people may drink wine to relieve their worries. The lack of a causal association in more than half of the nations under analysis implies that a wide range of variables outside the purview of our study, such as societal norms, prevailing economic situations, and public health regulations, may have an impact on the interaction between anxiety and alcohol consumption. Given the peculiar circumstances in Brazil, wherein alcohol consumption appears to induce anxiety akin to that of Granger, a more thorough comprehension of the cultural settings and drinking habits that would support the importance of such a link. Moreover, the data from Paraguay demonstrates a bidirectional link only with spirits, and Chile indicates a bidirectional relationship with spirits, highlighting the diverse nature of these correlations across various alcoholic beverage categories.

The significance of these discoveries for public health is clarified by this research. Argentina's bidirectional association across all alcohol patterns under investigation may be the result of larger economic and societal variables, such as the considerable influence of the wine industry and the comparatively cheap taxation of alcoholic drinks, which lure higher rates of young use. This emphasises the need for focused therapies and changes to legislation to lessen the impact of combined problems of alcohol misuse and anxiety disorders. The complex interplay between the perceived self-medicating effects of alcohol and the gender and age disparities in the incidence of depression and anxiety in Brazil further adds to the complexity of the situation. The need for public health initiatives that are responsive to these variations is further confirmed by these demographic characteristics as well as the wider effects of the COVID-19 pandemic. In overall, this study shows that although alcohol use plays a substantial role, and anxiety prevalence in South America

is not only caused by alcohol consumption. Understanding the influence of many other social variables, including social isolation, educational gaps, and economic instability are also vital. Future research should use more detailed models, such as structural equation modeling, which can better account for multiple interacting factors. For now, we advise cautious interpretation of our findings, recognising that both measured and unmeasured factors may affect the observed relationships. As a result, treating anxiety in this area necessitates a multidimensional strategy that considers problems associated with alcohol as well as more general social characteristics.

All things considered, these results serve as a call to action for academics, legislators, and public health authorities to have deeper insights into the complex relationships between alcohol consumption and mental health. There is a strong case for the creation of specialised, culturally sensitive therapies that target the underlying systemic causes of alcohol consumption habits and anxiety symptoms. Furthermore, the observed regional variations suggest that nation-specific strategies are required to effectively address the public health issues brought on by the co-occurring disorders of anxiety and alcoholism.

This study is based on the complex relationship between anxiety and alcohol consumption, which is influenced by a wide range of variables such as public health policy, culture and economy. Further research is required to clarify the underlying mechanisms of the relationship and the need for customised public health care initiatives. Based on this, it will build the foundation of future research in different countries. To sustain the well-being of a country or a society, implementing policies at various levels is a must. In this way, a country's economy can be strengthened through developing the quality of life of its citizens by preventing the spread of anxiety and excessive alcohol consumption.

Alcohol consumption problems such as social drinking, problem drinking, and unsafe drinking are considered public health problems. Alcohol control policies encompass laws, regulations and instructions aimed at preventing and mitigating alcohol-related harm. Alcohol policies can be worldwide, territorial, regional or national and with varying magnitudes. Effective alcohol control measures require policy reconciliation that includes a multi-component approach such as access, cost and promotion. The WHO Member States should devise and implement strategies along with vital measures to alleviate alcohol-related diseases and harm caused by alcohol consumption. Several countries have banned alcohol to eliminate the purchase or consumption of alcohol. Many states in the America do not have national composition alcohol laws imposed, which is

a must to strike a balance in upward revisions in government taxes and to mitigate public health issues as discussed.

Efforts should be made to develop effective policies against domestic violence in low-income countries such as Peru, Bolivia and Ecuador. Rise in anxiety levels is major cause of concern in such countries that calls for implementing policies, awareness programmes and making provisions for social protection to strengthen families' economies.

Supplementary Information

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Supplementary Material 1. S1 Appendix. Data file.
 Supplementary Material 2. S2 Appendix. Descriptive statistics for the dataset.
 Supplementary Material 3. S3 Appendix. Wine consumption in the South American continent.
 Supplementary Material 4. S4 Appendix. Beer consumption in the South American continent.
 Supplementary Material 5. S5 Appendix. Spirit consumption in the South American continent.
 Supplementary Material 6. S6 Appendix. LLC unit root test.

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Identifying information/images

Not applicable.

Authors' contributions

RJ conceptualised the study. DP, BS, RJ, LR and CW contributed to the design and conduction of the study. DP and BS curated the data. DP, BS, RJ, LR and CW undertook data analysis and interpreted the data. DP and BS drafted the first manuscript. All authors critically reviewed, edited, and approved the final manuscript.

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Availability of data and materials

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

Declarations

Ethics approval and consent to participate

This study was approved by the Sri Lanka Institute of Information Technology, Sri Lanka (PVC/RI/EC/2023/03).

Consent for publication

Not applicable (N/A).

Competing interests

The authors declare no competing interests.

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