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What does it drive the relationship between cardiovascular disease mortality and economic development? New evidence from Spain

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Abstract

Background During the last decades, there has been a great interest on the link between macroeconomic conditions and health. More precisely, many studies had studied as health outcome cardiovascular disease mortality, focusing in different countries, determinants, and using numerous econometric techniques. Due to its importance, in this paper, we analyse cardiovascular disease mortality across the 17 Spanish regions over the period 2002–2019.

Methods In doing so, we estimated several panel data models considering differences by sub-periods of time while also considering gender differences. That is, we transmit a difference on previous evidence by considering a longer period of time and different explanatory factors, so we provide new highlights for Spain.

Results Our empirical results show that: (i) both socioeconomic and environmental factors have a significant importance; (ii) political factors appear not to be significant; and (iii) there exists a Mediterranean (macro-region) cardiovascular disease mortality pattern.

Conclusions These results may have usefulness for cardiovascular disease mortality prevention in Spain.

Keywords Cardiovascular disease mortality, Economic development, Panel data, Spain

Background

There is widely empirical literature on the link between macroeconomic conditions and health, outcomes and results. That is, the empirical literature shows that macroeconomic conditions can significantly influence the health of populations, affecting both access to health services and overall health outcomes. Precisely, there is a particular interest in mortality [1]. In fact, since the seminal paper of Ruhm [2] it could be said that there have appeared several studies that analyse the relationship between economic conditions and health, while using both different data and econometric techniques. But, there is not yet a consensus about mortality being countercyclical or procyclical.

In this regard, one of the main health outcomes studied in this literature on macroeconomic conditions and health, is cardiovascular disease mortality (CVDM). This circumstance is not unexpected since cardiovascular diseases (coronary heart disease, cerebrovascular disease, rheumatic heart disease and other conditions) are the

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leading cause of death around the globe, taking around 17.9 million lives each year [3]. Moreover, it imposes a substantial economic burden in developed countries [4].

The relationship between cardiovascular disease (CVD) and gross domestic (Gross Domestic Product, GDP) is multifaceted and is influenced by several factors. Firstly, a higher GDP can lead to better health outcomes, including lower mortality rates from CVD due to improved treatment options and healthcare access. Secondly, a higher GDP typically correlates with socio-economic factors such as better education levels, which promote healthier lifestyle choices and greater awareness of health risks associated with CVD. Thirdly, environmental factors like pollution and urbanization can exacerbate the risk of CVD; however, wealthier nations may invest in green spaces that encourage physical activity, mitigating some risks. Indeed, as pointed by Kelly and Fuster [5] there is complex interaction among average per capita income in a country, trends in lifestyle, and other risk factors, and health systems capacity to control CVD.

Then, different studies have analysed, using as proxies for macroeconomics conditions data related with income (GDP) or unemployment rates, CVDM. Besides, recent studies have highlighted the harmful impact on several health outcomes (including cardiovascular health) such as concentration of pollutants [6–7] and/or economic and policy uncertainly [8–9].

In this respect, Spiteri and von Brockdorff [6] examined the connection between economic development and health outcomes. Initially, they estimated an empirical model utilizing data on annual mortality rates from cardiovascular diseases across a panel of European countries, along with the per capita GDP levels for each country. Additionally, they incorporated several other factors influencing health outcomes as outlined in the literature, which include various socio-economic, lifestyle, and environmental/contextual variables. For these environmental/contextual variables, total emissions of fine particulate matter (PM2.5) were considered. In fact, in the review by Al-Kindi et al. [7] it is highlighted how air pollution is the most important environmental cardiovascular risk factor, with fine particulate matter (PM2.5) and ozone gas being the most-studied air pollutants.

As for economic and policy uncertainly, both Kawachi et al. [8] and Kyriopoulos et al. [9] found that economic uncertainty is positively and significantly associated with cardiovascular disease mortality. So, they uncovered yet another risk factor for cardiovascular health and emphasized the significance of uncertainty alongside current economic developments and conditions. That is to say, they illustrated how uncertainty acts as a stressor and a catalyst for cardiovascular mortality. In their approximations both trusted on the Economic Policy Uncertainty (EPU) index.

In this framework, Spain provides a good scenario to examine deaths from cardiovascular diseases because since the "Great Recession" this country has experienced one of the poorest economic circumstances [10]. In Spain, according to the latest report from the National Institute of Statistics [11] on the causes of death, cardiovascular disease continues to be the leading cause of death, representing 26% of all deaths, being therefore above cancer (24,8%) and respiratory system diseases (19.3%).

Our main objective is to study the determinants/factors and patters of CVDM using regional data for 2002–2019 from Spain. The analysis is also conducted for three distinct key business cycle periods of this century in Spain: (i) "Great Expansion" (2002–2007), (ii) "Great Recession" (2008–2013), and (iii) "Recovery" (2014–2019). Besides, the analysis is stratified by sex. Therefore, we use panel data models in the methodology. In order to do so, we transmit a difference on previous studies by considering both a longer period of time and different explanatory factors, so we provide new highlights for CVDM prevention in Spain.

Methods

In order to analyse the different indicators/factors through which deaths from cardiovascular diseases may be affected in Spain, while also identifying patters, three 6-year periods according to three different business cycles scenarios are studied[1,2]: 2002–2007 (named as "Great Expansion"), 2008–2013 (denoted as "Great Recession"), and 2014–2019 (known as "Recovery"). The units under examination are the 17 Spanish regions.

In doing so, we consider four subgroups of indicators/factors: (i) socioeconomic, (ii) environmental, (iii) political, and (iv) regional. All in all, the selected variables are based on restrictions with data and the insights obtained from previous empirical evidence (highlighted in the Background section).

Precisely, we used regional annual data on deaths from diseases of the circulatory system. To obtain data for cause-specific mortality, we relied on the Spanish National Institute of Statistics (INE) after that, the authors calculated the mortality rates adjusting by the corresponding population data also available in the INE (Population Structure Indicators - resident population by date, sex and age (since 1971) by Autonomous Communities). Being this variable our dependent one. This variable is used both considering total population and distinguishing by gender.

As for independent variables, annual gross domestic product per capita, measured in current euros, would

[1] The Covid-19 period in not considered.

[2] Nonetheless, results are compared with the full sample period 2002–2019.

Table 1 Description of variables and sources

Category	Variable	Description	Source
Dependent variable	Cardiovascular disease mortality rate (CVDM)	Deaths by cardiovascular diseases per 100 000 population (crude rates)	Spanish National Institute of Statistics (INE) and authors' elaboration.
Socioeconomic explanatory variable	GDP per capita (GDPpc)	Annual Gross Domestic Product (GDP) per capita, measured in current euros	Spanish National Institute of Statistics (INE).
Environmental explanatory variable	$PM_{2.5}$	Population-weighted average of annual average $PM_{2.5}$ concentration (µg/m3)	Spanish National Institute of Statistics (INE).
Political explanatory variable	EPU	Economic Policy Uncertainty Index for Spain	Andres-Escayola et al. [12]
Regional explanatory variable	Mediterranean	1 if the region is located on the "Mediterranean area" of Spain, 0 otherwise	Authors' elaboration.

Source: Authors' elaboration

be used to collect the socioeconomic context. This variable is obtained through the Spanish regional accounting section of the INE. Besides, population-weighted average of annual average PM2.5 concentration (µg/m3) is the one selected to measure the environmental regional factors. This information is available also through the INE. Exactly, this can be found in the periodical publications-quality of life indicators-environment and environment. In addition, to capture political factors the Economic Policy Uncertainty Index for Spain is used. This indicator is obtained from Andres-Escayola et al. [12]. The information considered is the total annual average calculated by the authors. This variable will be common for the entire territory. Finally, a dummy for a macroregion, Mediterranean, is created to study in deep the regional factors. Table 1 summarized the variables used and their sources of information.

The empirical method is so based on panel data models. Our model generally becomes as follows:

$$lnCVDM_{it} = f\,(\,x_{it}\,,\,\beta\,) + \epsilon_{\,it} \tag{1}$$

where:

i = Region (where i = 1,..., 17),

t = Year (where t = 2002,..., 2019),

Ln = Natural logarithm,

X_{it}= Matrix of explanatory variables,

β = Vector of parameters to be estimated,

$\epsilon_{\,it}$= Error term.

In our empirical estimates, in order to correct equally possible problems of contemporaneous correlation and heteroscedasticity, panel-corrected standard errors (PCSE) are used.

Then, derived from Eq. (1), the general specification in this study can be described as follows:

$$lnCVDM_{it} = (x\prime_{\,it}\,\beta\,) + \alpha_{\,i} + \epsilon_{\,it} \tag{2}$$

where $\alpha_{\,i}$ is a region-specific effect.

As a result, Eq. (3) represents our final specification:

Table 2 Summary statistics

Variable	Mean	Standard Deviation	Maximum	Minimum
CVDM_total	280.649	57.978	148.460	420.510
CVDM_females	260.355	52.199	143.930	381.410
CVDM_males	300.398	64.387	144.130	460.350
GDPpc	22,337.250	4750.933	11592.000	36206.000
$PM_{2.5}$	12.536	3.610	6.300	29.000
EPU	111.633	41.577	57.910	222.483
Mediterranean	0.353	0.479	0	1

Notes: Observations are 306 for all variables except $PM_{2.5}$ that equals 202 (information is not available for the entire period nor is it completely identical for the regions)

Source: Authors' elaboration

Table 3 Cardiovascular disease mortality (persons) by sub-periods (Spain, total regions)

	Full period 2002–2019	Great expansion 2002–2007	Great recession 2008–2013	Recovery 2014–2019
Total	2,192,433	751,240	719,886	721,307
Females	1,190,640	408,924	392,410	389,306
Males	1,001,793	342,316	327,476	332,001

Source: Authors' elaboration

$$\begin{aligned} lnCVDM_{it} = \alpha_{\,i} + \beta_{\,1}\,(lnGDPpc_{it}) + \\ \beta_{\,2}\,(lnPm2.5_{it}) + \beta_{\,3}\,(lnEPU_t) + \\ \beta_{\,4}\,(\,Mediterranean_i) + \epsilon_{\,it} \end{aligned} \tag{3}$$

Further information about the variables is provided both in Tables 2 and 3. Specifically, in Table 2, the summary statistics are presented. Besides, cardiovascular disease mortality (in persons) total and by sub-periods is shown in Table 3.

Based on our initial analysis of the data, we observe a decline in mortality rates from cardiovascular disease during the period from 2019 to 2022. Furthermore, it appears that women are more significantly impacted than men. While cardiovascular disorders are a major cause of death for both genders, women tend to have a poorer prognosis. However, we will provide a more detailed descriptive analysis, complete with figures, in the following results section.

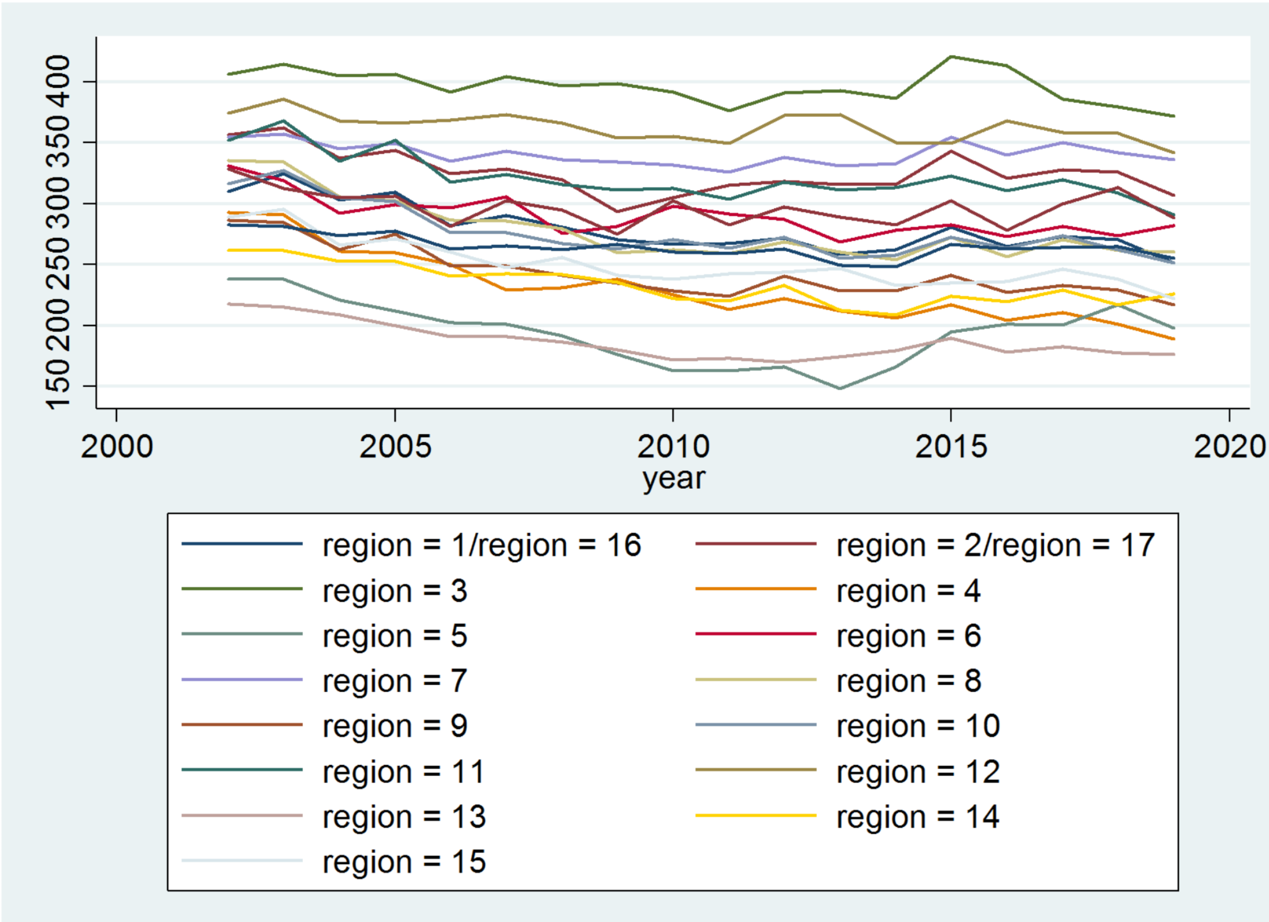

Fig. 1 Evolution of cardiovascular disease mortality (deaths per 100,000-crude rates) by Autonomous community in Spain (17 regions)
Notes: Andalusia (region = 1), Aragon (region = 2), Asturias (region = 3), Balearic Islands (region = 4), Canary Islands (region = 5), Cantabria (region = 6), Castile and Leon (region = 7), Castile-La Mancha (region = 8), Catalonia (region = 9), Valencian Community (region = 10), Extremadura (region = 11), Galicia (region = 12), Madrid (region = 13), Murcia (region = 14), Navarre Community (region = 15), Basque Country (region = 16), and La Rioja (region = 17)
Source: Authors' elaboration

Results

In order to gain a better understanding of the data, we explore cardiovascular disease mortality (our dependent variable), both across time and regions. Hence, in Fig. 1 it is plotted the evolution of CVDM (deaths per 100,000-crude rates) by regions. Regarding gender differences, Fig. 2 represents the distribution macro-regions.[3,4]

It can be observed, as was previously highlighted, a reduction under the period under study. Moreover, that the highest percentages are for Northern regions whereas the lowest are form Mediterranean ones. As was announced, higher percentages are for females.

The empirical results are presented in Tables 4, 5, 6 and 7. Thereby, in Table 4 results for the full period (2002–2019) are presented both for totals and disaggregating by gender.

Besides, Tables 5, 6 and 7 contain by subsamples (total, females, and males) the comparative results by the above-mentioned sub-periods of time ("Great Expansion", "Great Recession", and "Recovery").

From all these tables it can be observed that the coefficients are statistically significant and have, in most of the cases, the expected sign. Besides, it can be appreciated that the findings are robust and consistent by gender and by sub-periods of time. Then, focusing in our four subgroups of indicators/factors (socioeconomic, environmental, political and regional) it can be highlighted the following insights.

On the one hand, per capita GDP, has a negative/reverse effect on the mortality rates due to cardiovascular diseases. That is, an increase in GDP would lead a

[3] As climatic factors could play a major role when explaining health results from cardiovascular diseases [13], three macro-regions are considered: North, Mediterranean and Centre.

[4] North (Asturias, Cantabria, Galicia and Basque Country), Mediterranean (Andalusia, Balearic Islands, Canary Islands, Catalonia, Valencian Community and Murcia), Centre (Aragon, Castile and Leon, Castile-La Mancha, Extremadura, Madrid, Navarre Community and La Rioja).

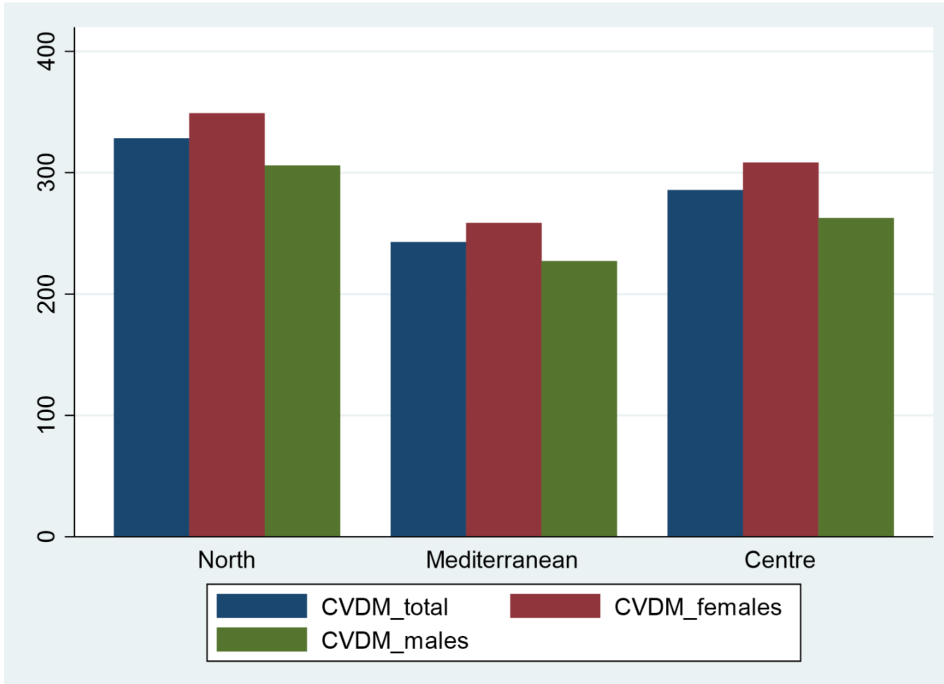

Fig. 2 Distribution of cardiovascular disease mortality (deaths per 100,000-crude rates) by macro-region (North, Mediterranean, Centre), mean 2002–2019
Source: Authors' elaboration

Table 4 Cardiovascular disease mortality (deaths per 100,000-crude rates), panel-corrected standard error (PCSE), considering gender differences, 2002–2019

Variable	Log CVDM_total		Log CVDM_females		Log CVDM_males	
Ln GDPpc	-0.522	***	-0.558	***	-0.482	***
	(0.029)		(0.029)		(0.030)	
Ln Pm$_{2.5}$	0.184	***	0.239	***	0.122	***
	(0.046)		(0.052)		(0.041)	
Ln EPU	0.029		0.051		0.004	
	(0.049)		(0.050)		(0.049)	
Mediterranean	-0.299	***	-0.330	***	-0.261	***
	(0.014)		(0.015)		(0.014)	
Constant	10.319	***	10.519	***	10.110	***
	(0.313)		(0.327)		(0.313)	
R-squared	0.454		0.497		0.384	
Wald chi2	985.45		968.42		878.70	
Prob > chi2	0.000		0.000		0.000	

Notes: Standard errors are reported in parenthesis. ***, ** and * denote significant at 1%, 5%, and 10%. Observations: 220

reduction in mortality. On the other hand, $PM_{2.5}$ concentration shows a positive effect on cardiovascular disease mortality. Thus, an increase in this pollutant would result in an increase in mortality. Surprisingly, no significant effect is found for Economic Policy Uncertainty. Finally, the Mediterranean regional factor appears to have a negative relationship with CVDM. Therefore, climatic factors could play a major role when explaining health results from cardiovascular diseases.

Discussion

This study complements to previous recent studies done for Spain such as the one of Regidor el al. [14] or Cervini-Plá and Vall-Castelló [1] that analysed economic circumstances and mortality in Spain, or those form the international perspective that specially focus on cardiovascular disease mortality and economic development such as Spiteri and von Brockdorff [6].

Our preliminary analysis showed a decrease in CVDM during the period under consideration and that the lowest values were found by Mediterranean regions. Indeed,

Table 5 Cardiovascular disease mortality (log *CVDM_total*), panel-corrected standard error (PCSE), considering sub-periods of time

Variable	Full period 2002–2019		Great expansion 2002–2007		Great recession 2008–2013		Recovery 2014–2019	
Ln GDPpc	-0.522	***	-0.477	***	-0.555	***	-0.525	***
	(0.029)		(0.026)		(0.020)		(0.041)	
Ln Pm$_{2.5}$	0.184	***			0.274	***	0.259	***
	(0.046)				(0.063)		(0.055)	
Ln EPU	0.029		0.017		-0.013		-0.115	
	(0.049)		(0.060)		(0.025)		(0.180)	
Mediterranean	-0.299	***	-0.170	***	-0.319	***	-0.332	***
	(0.014)		(0.014)		(0.017)		(0.016)	
Constant	10.319	***	10.394	***	10.610	***	10.924	***
	(0.313)		(0.396)		(0.239)		(0.915)	
Observations	220		102		95		102	
R-squared	0.454		0.487		0.493		0.515	
Wald chi2	985.45		345.07		2427.70		1054.22	
Prob > chi2	0.000		0.000		0.000		0.000	

Notes: Standard errors are reported in parenthesis. ***, **, and * denote significant at 1%, 5%, and 10%

Table 6 Cardiovascular disease mortality (log *CVDM_females*), panel-corrected standard error (PCSE), considering sub-periods of time

Variable	Full period 2002–2019		Great expansion 2002–2007		Great recession 2008–2013		Recovery 2014–2019	
Ln GDPpc	-0.558	***	-0.523	***	-0.581	***	-0.573	***
	(0.029)		(0.028)		(0.018)		(0.040)	
Ln Pm$_{2.5}$	0.239	***			0.339	***	0.317	***
	(0.052)				(0.075)		(0.057)	
Ln EPU	0.051		0.000		-0.002		-0.125	
	(0.050)		(0.064)		(0.027)		(0.177)	
Mediterranean	-0.330	***	-0.173	***	-0.348	***	-0.364	***
	(0.015)		(0.016)		(0.020)		(0.017)	
Constant	10.519	***	10.988	***	10.746	***	11.379	***
	(0.327)		(0.427)		(0.242)		(0.901)	
Observations	220		102		95		102	
R-squared	0.497		0.502		0.532		0.561	
Wald chi2	968.42		346.39		2036.57		731.38	
Prob > chi2	0.000		0.000		0.000		0.000	

Notes: Standard errors are reported in parenthesis. ***, **, and * denote significant at 1%, 5%, and 10%

Table 7 Cardiovascular disease mortality (log *CVDM_males*), panel-corrected standard error (PCSE), considering sub-periods of time

Variable	Full period 2002–2019		Great expansion 2002–2007		Great recession 2008–2013		Recovery 2014–2019	
Ln GDPpc	-0.482	***	-0.423	***	-0.527	***	-0.472	***
	(0.030)		(0.024)		(0.024)		(0.043)	
Ln Pm$_{2.5}$	0.122	***			0.200	***	0.194	***
	(0.041)				(0.053)		(0.056)	
Ln EPU	0.004		0.033		-0.026		-0.100	
	(0.049)		(0.058)		(0.023)		(0.185)	
Mediterranean	-0.261	***	-0.167	***	-0.284	***	-0.294	***
	(0.014)		(0.011)		(0.015)		(0.016)	
Constant	10.110	***	9.725	***	10.493	***	10.393	***
	(0.313)		(0.374)		(0.261)		(0.946)	
Observations	220		102		95		102	
R-squared	0.384		0.435		0.428		0.440	
Wald chi2	878.70		334.90		2775.67		1361.43	
Prob > chi2	0.000		0.000		0.000		0.000	

Notes: Standard errors are reported in parenthesis. ***, **, and * denote significant at 1%, 5%, and 10%

different studies had addressed climatic influences on cardiovascular diseases [13]. In this regard, Achebak et al. [15] studied, in Spain, the temporal changes in the effect of ambient temperature on both age-specific and sex-specific cardiovascular mortality risk. Also, the highest values were for females [16].

Furthermore, our empirical results have highlighted the relevance of both socioeconomic and environmental factors over time. Then, our findings are in accordance with the results of the review by Lago-Peñas et al. [17] who concluded that, in OECD countries, low socioeconomic status appears to have a consistent and significant effect on mortality and morbidity caused by noncommunicable diseases and with Hayes et al. [18] that pointed out the relevance of air quality cardiovascular disease mortality.

However, no significant effects for political factors have been observed in this study. One possible explanation is that we focus on cardiovascular disease mortality and not study neither cardiovascular disease events nor its derived hospitalizations. Besides, the findings must be considered in light of the Spanish national health care system (universal). Furthermore, we relied on yearly data. All in all, in spite not reporting in this study significant results for EPU, exploring more in deep its effects in future research, when more data would be offered, would be really interesting. Specifically, analysing the COVID-19 pandemic and later period outcomes (subsequent 6-year period: 2020–2025) and, when possible, using monthly versus yearly data.

This study is subject to limitations and we must comment on them. First of all, we only work with aggregate/macro data, so we cannot control for individual characteristics that could affect to CVDM. In second place, other important factors, such as those related with lifestyles and/or psychological ones, due to lack of information at a macro-region level could not be finally included.

Anyhow, our results may have some usefulness for cardiovascular disease control and prevention in Spain. That is, public health strategies should consider these facts when trying to do an efficient use of (the scarce) resources. As macro-level circumstances have been highlighted, it would be advantageous to create particular policy measures to counter major events that give rise to them, such as: low income and/or high concentration of pollutants. What is more, due to the importance of CVDM it should be a priority of the national health care system to guarantee equitable access to cardiovascular technologies, which had been proved as stated by De la Torre Hernández et al. [19] to have led to considerable advances in cardiology and a notable reduction in CVDM.

Conclusions

The goal of this study was to analyse the different determinants/factors through which deaths from cardiovascular diseases may be affected in Spain while also identify patterns and during the 21st century. The analysis has been developed for the 17 Spanish regions during the period 2002–2019, while considering different sub-periods, here understood as: (i) "Great Expansion", (ii) "Great Recession", and (iii) "Recovery". The results have highlighted: (i) the importance of both socioeconomic and environmental factors; (ii) that political factors appear not to be significant; and (iii) that there exists a Mediterranean (macro-region) cardiovascular disease mortality rule.

Abbreviations

CVDM	Cardiovascular disease mortality
CVD	Cardiovascular disease
GDP	Gross Domestic Product
INE	Spanish National Institute of Statistics

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Author contributions

All the authors contributed to the writing of the manuscript and read and approved the final manuscript. Conceptualization: C.B-F. and D.C-P.; Methodology: C.B-F. and D.C-P.; Formal analysis: C.B-F.; Writing - Original Draft: C.B-F.; Writing - Review & Editing: C.B-F. and D.C-P.; Supervision: D.C-P. The corresponding author, C.B-F., on behalf of the other authors guarantee the accuracy, transparency and honesty of the data and information contained in the study, that no relevant information has been omitted and that all discrepancies between authors have been adequately resolved and described.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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