TESIS DE LA UNIVERSIDAD DE ZARAGOZA

2025

187

Ana Ledesma Cuenca

Ensayos sobre Econometría de la salud, crecimiento y medio ambiente, desde una perspectiva de género

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http://zaguan.unizar.es/collection/Tesis

ISSN 2254-7606

Prensas de la Universidad
Universidad Zaragoza

Universidad de Zaragoza
Servicio de Publicaciones

ISSN 2254-7606

Universidad Zaragoza
1542

Tesis Doctoral

ENSAYOS SOBRE ECONOMETRÍA DE LA SALUD, CRECIMIENTO Y MEDIO AMBIENTE, DESDE UNA PERSPECTIVA DE GÉNERO

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Tesis Doctoral / PhD Thesis

Ensayos sobre Econometría de la salud, crecimiento y medio ambiente, desde una perspectiva de género

Studies on Health Econometrics, Growth, and the Environment from a Gender Perspective

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Programa de Doctorado en Economía

Phd in Economics

Facultad de Economía y Empresa

2024

Aknowledgements

I would like to express my heartfelt gratitude to all those who have been fundamental in the development of my thesis. Without their support, guidance, and encouragement, I would not have been able to complete this project, which holds such significance for me.

I wish to begin by expressing my deepest thanks to my thesis supervisors, Antonio Montañés and Blanca Simón. I am especially grateful to Antonio for his academic rigour, technical expertise, and invaluable contribution to the structuring and methodological development of the thesis. His critical approach and dedication have been essential to the progress of this thesis. Blanca, on the other hand, deserves my most sincere appreciation. Over the years, she has been not only a mentor but also a friend and guide, always willing to offer her support, insight, and wisdom at every stage of my academic career. Her support, both academically and personally, has been vital to my professional growth, and I cannot express enough gratitude for all she has done.

I would also like to extend my thanks to the Department of Economic Analysis at the University of Zaragoza, for providing an enriching academic environment, and to all its members, with whom I have had the privilege of working over the years. To my research group colleagues, whose collaboration and input have enriched and strengthened my research, I am deeply grateful. I would also like to express my heartfelt thanks to my office colleagues, as our daily interactions, exchange of ideas, and the spirit of fellowship we created have been a source of essential support during moments of uncertainty and on the most demanding days. Without their company, this academic journey would not have been the same.

In particular, I would like to acknowledge Alejandro Alcay, who has been an invaluable support in developing various aspects of my thesis. And, of course, Bárbara Baigorri. I owe Bárbara not only my appreciation for her collaboration and advice but also for the joy and friendship that have defined these years. Since we began this journey together, she has been an unwavering friend, someone with whom to share both challenges and achievements, and who made each day of this doctorate lighter and more meaningful. Without her, this experience would have been vastly different; her presence has made every challenge feel more manageable and each success even more fulfilling.

Regarding my time in Albania, I would like to express my sincere gratitude to my supervisor abroad, Skender Uku, for giving me the opportunity to live my first international experience and to work in a foreign university setting.

Naturally, I cannot overlook expressing my profound gratitude to my family, whose love, support, and understanding have been the foundation of my entire life. To my parents, Javier and Mercedes, who have always encouraged me to pursue my dreams and have been by my side at every step, I owe my strength and my motivation to continue, even in times of difficulty. Their dedication has given me the confidence to reach my goals. And to my cousin Susana, who has been with me since I was young, I am deeply grateful for her support, which has been a fundamental pillar for me, and I am immensely thankful to have her by my side.

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Resumen (Spanish)

En los últimos años, el análisis de la relación entre economía y salud ha cobrado fuerza a través de organismos e instituciones internacionales. Desde la aprobación de la Agenda 2030 para el Desarrollo Sostenible, mantener el carácter universal, público y gratuito del sistema sanitario, garantizar su sostenibilidad, y promover el bienestar de todas las personas, independientemente de su edad o de su género, es uno de los Objetivos de Desarrollo Sostenible (ODS) de los países de la Organización para la Cooperación y el Desarrollo Económico (OCDE).

Tras la llegada del COVID-19 los debates en materia de salud se han intensificado y se ha aceptado por todos los estamentos que la defensa de la salud de la población ha sido y es un aspecto primordial para los agentes de gobierno (Khan *et al.*, 2020; Llamazares, 2020; López-Mendoza *et al.*, 2021). La pandemia nos ha mostrado que nuestro planeta y nuestra sociedad afrontan enormes retos, como cambios en la estructura de la población, la evolución de los patrones de enfermedad, la persistencia de las desigualdades de género en salud y el cambio climático, que suponen un desafío para los sistemas sanitarios actuales (Rajmil y Fernández de Sanmamed, 2019; McCartney *et al.*, 2019; Gavurova *et al.*, 2020). Por ello, la salud no ha de entenderse de manera aislada, ya que no solo está influenciada por factores biológicos, sino también por condiciones sociales, económicas y ambientales que afectan desigualmente a diferentes grupos de la población (Dahlgren and Whitehead, 2021; Álvarez-Gálvez *et al.*, 2023). En consecuencia, es necesario adoptar un enfoque holístico que considere como estas variables se influyen mutuamente.

Por ello, nuestro punto de partida es la relación entre los ODS que definen el futuro de la salud, el crecimiento sostenible y la conservación del medio ambiente, considerando no solo los aspectos relacionados con la desigualdad de género en salud, sino cómo las dinámicas de género influyen en el acceso a los recursos, en las oportunidades socioeconómicas y sociales, y en los impactos del cambio climático, especialmente en contextos de recesión económica.

En particular, creemos que esta perspectiva puede definir el futuro de la salud de una sociedad. En primer lugar, porque las políticas de crecimiento basadas en la sostenibilidad brindan una clara oportunidad de mejora de la salud y, como consecuencia, del propio bienestar social. En segundo lugar, porque la creciente literatura sobre la sostenibilidad

del medio ambiente indica que la contaminación atmosférica tiene un efecto directo en la salud de la población (Leksell y Rabl, 2001; Li *et al.*, 2019; Kayani *et al.*, 2020; Mutjaba and Shahzad, 2021). Y, en tercer lugar, porque la integración de enfoques sensibles al género en la formulación de políticas y la implementación de programas es fundamental para cerrar las brechas existentes y garantizar un futuro equitativo y sostenible para todos (Llorens-Ortega *et al.*, 2024).

En esta línea, entendemos el concepto de salud cómo un estado de completo bienestar físico, mental y social, y no solamente la ausencia de afecciones o enfermedades, según Organización Mundial de la Salud (OMS). En la literatura se destaca la esperanza de vida al nacer y la tasa de mortalidad, como indicadores de salud comúnmente utilizados (Martín Cervantes *et al.*, 2019; Park y Nam, 2019). Sin embargo, estos indicadores no capturan las muertes tempranas y potencialmente prevenibles. Por ello, hemos seleccionado la mortalidad prematura, como variable clave en la evaluación del estado de salud. Este concepto se refiere a la pérdida de años de vida durante periodos económicamente productivos (Aghion *et al.*, 2010), y suele medirse a través de los Años Potenciales de Vida Perdidos (PYLL, por sus siglas en inglés). Su impacto es significativo no solo en el bienestar de las personas y sus familias, sino también en la economía y la estabilidad social en general. Además, este indicador es más sensible a las disparidades dentro de una población, y destaca problemas en subpoblaciones vulnerables que la esperanza de vida no revela, como la desigualdad de género en salud. Asimismo, tiene en cuenta la morbilidad, dando una imagen más completa del estado de salud de la población (OCDE, 2024).

Consideramos que una de las aportaciones importantes de la tesis es que aborda una brecha significativa en el estudio de las intersecciones entre salud, economía y medio ambiente, relacionada con la omisión o insuficiente consideración de la perspectiva de género. En muchos análisis, la dimensión de género no es considerada, lo que lleva a una visión incompleta y sesgada de los problemas en salud (Clougherty, 2010). Mientras que, en los casos en los que se considera, a menudo no hay consenso en la literatura, lo que refleja la falta de un marco conceptual sólido que integre plenamente las dinámicas de género (Sillman *et al.*, 2022).

También encontramos que, en los estudios previos, el análisis de la salud se ha realizado principalmente desde una perspectiva de corte transversal, utilizando encuestas que capturan un momento específico en el tiempo (Jakovljevic and Ogura, 2016; Varbanova and Beutels, 2020; Cezard *et al.*, 2021). Sin embargo, la salud es el resultado de un proceso acumulativo influenciado por factores que actúan a lo largo del tiempo. Por ello, para comprender realmente el estado de salud de una población, es necesario analizarla en un marco temporal amplio. Siguiendo esta visión, la tesis va a usar eminentemente herramientas propias del análisis de series temporales. Este tipo de técnicas tienen claras ventajas frente el uso más estándar de datos de corte transversal, ya que permiten incorporar el componente dinámico de las series. Además, permiten observar si las tendencias han experimentado rupturas debido a algún acontecimiento extraordinario (es el caso de la Gran Recesión o de la pandemia por COVID-19), y si esos cambios han exacerbado las disparidades en salud entre géneros.

De esta manera, el objetivo principal de la tesis es usar técnicas de econometría de series temporales para analizar las posibles relaciones existentes entre tres líneas prioritarias de la Agenda 2030 como son la salud, el crecimiento sostenible y el cuidado del medio ambiente, tanto a nivel nacional como a nivel supranacional. Integrando también la perspectiva de género, permitirá desarrollar un análisis más preciso y equitativo que permita orientar el diseño de políticas públicas más justas, efectivas y adaptadas a las realidades de los diferentes grupos sociales.

Este objetivo general se desglosa en varios sub-objetivos analizados en la tesis doctoral:

* Examinar las disparidades internacionales en los resultados sanitarios
* Examinar el desempeño de los sistemas de salud y los factores socioeconómicos que influyen a nivel supranacional y nacional.
* Evaluar el vínculo entre la degradación del medio ambiente y la salud.
* Evaluar las desigualdades en salud entre géneros a nivel supranacional y nacional.
* Evaluar el efecto del ciclo económico sobre la salud de la población

Para abordar adecuadamente dichos objetivos, la tesis se divide en tres capítulos, cada uno complementario al anterior. En el primer capítulo, analizamos la evolución de la mortalidad prematura en los países de la OCDE, concretamente determinando si este indicador de salud converge, o, por el contrario, diverge. Los resultados revelan el efecto de la Gran Recesión sobre las disparidades en mortalidad prematura y clarifican las fuerzas determinantes de la creación de grupos de convergencia. En el segundo capítulo, se evalúa cómo el crecimiento, el gasto sanitario y la contaminación del aire (previamente identificadas en el primer capítulo como factores que influyen en la convergencia de los países de la OCDE) influyen en la mortalidad prematura desagregada por género, observando si existen disparidades en el largo plazo, y si se ven afectadas por la Gran Recesión. Y, por último, en el tercer capítulo, examinamos los determinantes económicos, médicos y no médicos, que influyen en la mortalidad de hombres y mujeres en España.

Durante el desarrollo de la tesis, hemos abordado una perspectiva internacional, centrándonos en los países de la OCDE, que engloban las económicas más desarrolladas. Analizar el desempeño de estos países en salud y sostenibilidad del medio ambiente ofrece valiosas orientaciones para la formulación de políticas públicas, ya que, aunque los niveles de desarrollo y prosperidad de estos países son más elevados, continúan enfrentando desafíos importantes que han evolucionado con el tiempo. A su vez, la OCDE tiene un enfoque fuerte en el desarrollo sostenible, y el estudio de estrategias impulsadas por sus países miembros resulta fundamental para conocer políticas efectivas a la hora de abordar problemas contemporáneos, como el cambio climático y la transición hacia económicas más verdes, sostenibles y equitativas. En el tercer capítulo, nos hemos centrado en España, como miembro destacado de la OCDE, para conocer en detalle una evaluación comparativa por género del estado de salud a nivel nacional.

En cada capítulo se ha incluido una sección dedicada a la revisión de la literatura previa relacionada con el enfoque de ese capítulo, y una sección dedicada a la discusión de los resultados, implicaciones o recomendaciones sobre las políticas públicas derivadas de las principales conclusiones. Finalmente, se ha incluido un apartado que recoge las principales conclusiones generales del conjunto de la tesis doctoral. Cabe destacar que el primer capítulo de la tesis está publicado en la revista *Social Science & Medicine* bajo la referencia Ledesma *et al.* (2022). El segundo capítulo se encuentra en revisión y el tercero se enviará en un futuro próximo.

Abstract

In recent years, the analysis of the relationship between the economy and health has grown in strength through international organisations and institutions. Since the adoption of the 2030 Agenda for Sustainable Development, maintaining the universality of the health system, ensuring its sustainability, and promoting the well-being of all people, regardless of age or gender, is one of the Sustainable Development Goals (SDGs) of the Organisation for Economic Co-operation and Development (OECD) countries.

Since the onset of the COVID-19 pandemic, health-related debates have intensified. It has become widely acknowledged that safeguarding the health of the population is a primary objective of government actors (Khan *et al.*, 2020; Llamazares, 2020; López-Mendoza *et al.*, 2021). The pandemic has revealed that our planet and society confront significant challenges, including shifts in population structure, emerging disease patterns, ongoing gender inequalities in health, and climate change, all of which strain existing health systems (Hadad *et al.*, 2013; Rajmil and Fernández de Sanmamed, 2019; McCartney *et al.*, 2019; Gavurova *et al.*, 2020). Therefore, health should not be considered in isolation. It is influenced not only by biological factors but also by social, economic, and environmental conditions that affect different population groups unequally (Dahlgren and Whitehead, 2021; Álvarez-Gálvez *et al.*, 2023). Thus, it is necessary to adopt a holistic approach that considers how these variables influence each other.

Therefore, our starting point is the relationship between the Sustainable Development Goals (SDGs) that define the future of health, sustainable growth, and environmental conservation. We will consider not only the aspects related to gender inequality in health but also how gender dynamics influence access to resources, socioeconomic opportunities, and the impacts of climate change, especially in contexts of economic recession.

In particular, we believe that this perspective can define the future of a society's health. First, growth policies grounded in sustainability offer a clear opportunity to enhance health and, consequently, social welfare. Second, the increasing body of literature on environmental sustainability indicates that the air pollution has a direct impact on population health (Leksell and Rabl, 2001; Li *et al.*, 2019; Kayani *et al.*, 2020; Mutjaba and Shahzad, 2021). Third, integrating gender-sensitive approaches into policy

formulation and program implementation is crucial for closing existing gaps and ensuring an equitable and sustainable future for all (Llorens-Ortega *et al.*, 2024).

In this context, we define health as a state of complete physical, mental, and social well-being, and not just the absence of disease or illness, as outlined by the World Health Organization (WHO). The literature commonly identifies life expectancy at birth and mortality rates as standard health indicators (Martín Cervantes *et al.*, 2019; Park and Nam, 2019). However, these indicators fail to account for early and potentially preventable deaths. Consequently, we have selected premature mortality as a key variable for assessing health status. This concept refers to the loss of years of life during economically productive periods (Aghion *et al.*, 2010) and is frequently measured using Potential Years of Life Lost (PYLL). Its impact extends beyond individual and familial well-being, affecting the economy and social stability at large. Moreover, this indicator is more sensitive to disparities within a population and reveals issues in vulnerable sub-populations that life expectancy does not capture, such as gender inequality in health. It also includes morbidity, giving a more complete picture of the health of the population (OECD, 2024).

We consider that one of the important parts of the thesis is that it addresses a significant gap in the research on the intersections between health, economy and environment, related to the omission or insufficient consideration of the gender perspective. In many analyses, the gender dimension is overlooked, leading to an incomplete and biased view of health problems (Clougherty, 2010). Where it is considered, there is no consensus in the literature, reflecting the lack of a solid conceptual framework that fully integrates gender dynamics (Sillman *et al.*, 2022).

We also found that previous studies have primarily analysed health from a cross-sectional perspective, utilizing surveys that capture a specific moment in time (Hertz *et al.*, 1994; Jakovljevic and Ogura, 2016; Varbanova and Beutels, 2020; Cezard *et al.*, 2021). However, health is the result of a cumulative process influenced by factors that operate over time. Therefore, to understand better the health status of a population, it is essential to analyse it within a broad temporal framework. In line with this approach, the thesis will primarily employ time series analysis tools. This technique offers distinct advantages over the conventional use of cross-sectional data, as it allows for the incorporation of the dynamic components of the series. In addition, they allow us to observe whether trends have been subject to structural breaks due to some extraordinary event (e.g., the Great Recession or the COVID-19 pandemic) and whether these changes have exacerbated gender health disparities.

Therefore, the main objective of this thesis is to use time series econometric techniques to analyse the potential relationships between three priority areas of the 2030 Agenda: health, sustainable growth and environmental protection, at both national and supranational levels. Through the integration of a gender perspective, this approach will allow for a more precise and equitable analysis that can guide the design of more equitable and effective public policies tailored to the realities of different social groups.

This general objective is divided into several sub-objectives which are analysed in the doctoral thesis:

- Examining international disparities in health outcomes.
- Analysing the performance of health systems and the socio-economic factors that influence them at both supranational and national levels.
- Assessing the link between environmental degradation and health.
- Evaluating gender inequalities in health at supranational and national levels.
- Assessing the impact of the economic cycle on population health.

In order to adequately address these objectives, the thesis is divided into three chapters, each complementing the preceding one. In the first chapter, we analyse the evolution of premature mortality in OECD countries, in particular by determining whether this health indicator is converging or, on the opposite, diverging. The results indicate the impact of the Great Recession on disparities in premature mortality and clarify the determinant forces that contribute to the formation of convergence groups. The second chapter assesses how growth, health spending, and air pollution—previously identified in the first chapter as factors influencing convergence in OECD countries—affect gender-disaggregated premature mortality. It investigates whether disparities exist in the long-term effects and whether these disparities are influenced by the Great Recession. Finally, the third chapter examines the economic, medical, and non-medical determinants that influence mortality for male and female population in Spain.

Throughout the development of the thesis, we have adopted an international perspective, concentrating on OECD countries, which comprise some of the most developed economies. Analysing the performance of these countries in health and environmental sustainability provides valuable insights for policymaking. Although these nations enjoy higher levels of development and prosperity, they continue to confront significant challenges that have evolved over time. Moreover, the OECD places a strong emphasis on sustainable development. Understanding the strategies pursued by its member countries is crucial for identifying effective policies to contemporary issues such as climate change and the transition to greener, more sustainable, and equitable economies. In the third chapter, we focus on Spain, a leading member of the OECD. Its inclusion allows for a comparative assessment of health status at the national level.

Each chapter includes a section devoted to reviewing the relevant literature related to its focus, as well as a specific section dedicated to the discussion of the results, public policy implications or recommendations derived from the main conclusions. Finally, a section has been included which presents the general conclusions of the doctoral thesis. It is worth noting that the first chapter has been published in the journal *Social Science & Medicine* under the reference Ledesma *et al.* (2022). The second chapter is currently under revision, while the third chapter will be submitted in the near future.

Chapter I: Disparities in premature mortality: Evidence for the OECD countries

I.1. Introduction

The improvement of the health levels of its citizens is one of the main objectives of any society. Governments have continuously been allocating increasing resources to achieve the objectives set by various supranational organizations since the end of the last century. These include the resolution of September 25, 2015 of the United Nations Assembly, commonly known as the 2030 Agenda, which explicitly includes Health as one of its main objectives. Specifically, Sustainable Development Goal 3 aims to ensure healthy lives and promote well-being for all people, regardless of age. To achieve this goal, health policymakers face challenges such as economic and social crises, changes in population structure, evolving disease patterns, increasing health inequalities and environmental transformations that challenge health systems (Rajmil and Fernández de Sanmamed, 2019; McCartney *et al.*, 2019; Gavurova *et al.*, 2020).

The search for improvements in health levels has led to a significant increase in health spending since the second half of the last century, especially in the Organization for Economic Co-operation and Development (OECD) countries, an international group of countries that works to build better policies for better lives. This effort has been fruitful and has involved a significant increment in the health indicators of these countries, reducing mortality rates and increasing the life expectancy of their inhabitants. However, despite these generic improvements, it does not appear that the evolution of these health indicators has followed a similar pattern of behavior, as can be deduced from the results recently obtained by Liou *et al.* (2020) and Xu *et al.* (2021). Rather, it seems that the differences in the health levels between countries have grown. These disparities have generated some strange situations, for example where countries with similar levels of health spending do not exhibit similar levels of health, as noted in Barthold *et al.* (2014). Following Costa *et al.* (2021), this disparity in health levels could be interpreted as the result of an inefficient allocation of resources. This is a serious problem in economics, and it is especially so in a situation in which the COVID 19 crisis has raised public spending to very high levels, seriously aggravating the problems of unsustainability noted in Christopoulos and Eleftheriou (2020b) for the period previous to the outbreak of the pandemic. Health policymakers are therefore faced with the task of maintaining or improving the level of health of their fellow citizens under restrictive economic conditions, as noted by Reibling *et al.* (2019), which makes it extremely necessary to evaluate the evolution of health indicators.

In this regard, we should note that several indicators have been previously used in the literature to assess health system outcomes. The most frequently used are life expectancy at birth, adjusted mortality, infant mortality ratio and premature mortality, as seen in the papers by Martín Cervantes *et al.* (2019), Park and Nam (2019) and Varbanova and Beutels (2020), amongst many others. In our view, a very interesting alternative is the use of the Potential Years of Life Lost, hereafter PYLL. This indicator allows us to assess the loss suffered by society as a result of the death of young people or premature deaths. In addition, the assessment of PYLL rates allows us to advise and help guide state health units, as well as to identify new health problems that require the formation of new community policies (McDonnell *et al.*, 1998). Dickinson and Welker (1948) and Haenszel (1950) pioneered the use of this measure, observing that counting deaths did not give a complete picture of mortality, and that this can be complemented by PYLL. This health indicator is able to capture better the burden of loss and lifetime productivity.

Despite the above-mentioned improvement in health indicators, this does not seem to have behaved similarly in all the countries and it is possible to find disparities in the evolution of this. Quite an interesting method to analyze the existence of these disparities is convergence analysis, as Liou *et al.* (2020) note. In this regard, we should note the existence of a group of very interesting papers that have studied convergence in health indicators using the standard concepts of β- and σ-convergence. We can cite the papers of Jaworska (2014), Richardson *et al.* (2014), Maynou *et al.* (2015), Maynou and Saez (2016), Stańczyk (2016) and Hrzic *et al.* (2021), all of them focused on the European case, and Bremberg (2017) for the OECD case. Their conclusions are similar and the use of the standard concept of β-convergence suggests evidence in favor of convergence.

However, the results of Quah (1993) and Islam (2003) warn us against the use of this procedure, given that negative values of the parameter β from the growth-initial level regression do not necessarily imply a reduction in this dispersion. Then, these authors suggest it is better to focus on the analysis of the dispersion (σ-convergence).

Furthermore, we should also take into account the results of Baumol (1986) and Galor (1996), showing that the β- and σ-convergence analysis may be biased by the existence of convergence or groups of countries/regions that tend to the same steady-state equilibrium. These problems can be easily overcome by using the statistics recently designed by Phillips and Sul (2007, 2009), PS hereafter, which allows us to test the null hypothesis of convergence and, provided we reject it, determine the existence of convergence clubs.

Against this background, the aim of the paper is to analyse the evolution of premature mortality in OECD countries, measured by PYLL. More precisely, we apply the previously-mentioned PS methodology to determine whether this health indicator converges for the OECD countries or, by contrast, several convergence clubs co-exist. We also try to determine whether the Great Recession may have altered the convergence results. In this regard, we should note that this recent crisis dealt a severe blow to public policies (Keegan *et al.*, 2013; Karanikolos *et al.,* 2013; Basu and Bundick, 2017; Parmar *et al.*, 2016), which may have increased the differences in health outcomes between the countries studied (Rajmil and Fernández de Sanmamed, 2019). Then, we consider it of interest to analyse its possible effect. Finally, following the suggestions of Hrzic *et al.* (2020), we try to identify the forces that help us to understand the creation of the convergence clubs.

The rest of the paper is organized as follows. Section 2 describes the data, methodology and analysis framework. Section 3 presents the empirical results of the convergence analyses, a description of the clubs, and a discussion of the results, which includes economic implications and policy recommendations. Finally, Section 4 draws the most important conclusions.

I.2. Data and methods

I.2.1. Data

The paper focuses on the analysis of the PYLL. This is quite an interesting measure of health outcome given that if offers information on the premature mortality of a population, which has the capacity of reflecting the effectiveness of the health policies of a country better than alternative indicators such as life expectancy or mortality rate, as discussed in Romeder and McWhinnie (1977) and Gardner and Sanborn (1990). PYLL considers deaths that occur at an early age and may be avoidable. To that end, we first need a reference age limit. In the present case, this reference age limit is 70 years. Subsequently, deaths occurring at each age are summed and then multiplied by the number of years remaining until this reference age limit. The OECD standardizes the PYLL indicator for each country and each year to make comparisons between countries easier. It takes 2010 as the reference population for age standardization and is measured in years lost per 100,000 populations, aged 0-69 years. Our sample considers 33 OECD countries for the period 1990-2017 for which we have a complete data set which allows us to disaggregate by gender.

Table 1 presents some descriptive statistics of the PYLL variable. We can observe that there exist some gender differences, with female data showing the lowest values, as Asiskovitch (2010), Stefko *et al.* (2020) and the World Health Organization (WHO, 2021) also point out. Besides this, we can also observe that PYLL has shown a negative growth rate across the sample, although countries do not evolve in the same way. For instance, we note that the United States (female) and Costa Rica (male) exhibit the smallest decline in PYLL, with values close to 0 (-0.7% and -0.9%, respectively). By contrast, Korea shows the highest reduction in PYLL, with average growth rates of -3.6% and -3.8% for female and male, respectively. We can also observe that European countries have had relatively similar decreasing rates. This is not the case of Asian countries (Korea doubles the decreasing rates of Japan) or Latin American countries, where the behaviour of Mexico and Brazil is clearly different to that of Chile.

The analysis of the time evolution of the growth rates also offers us some interesting insights. To that end, we have split the sample in several segments in order to capture the possible effect of the Great Recession on the evolution of this variable. The first segment shows that the growth rates always take negative values for the female and the male cases, although the variation rank is somewhat different. The average growth rates go from -4.2% (Luxembourg) to -1.1% (United States) for the female case, whilst this interval goes from -4.1% (Luxembourg) to -1.4% (Costa Rica) for the male case. If we now consider the post Great Recession sample (2008-2017) we observe that some countries exhibit positive growth rates, especially in the male case, and that the variation of this average growth rate also increases. In particular, the behaviour during the last considered segment is especially heterogeneous. We can observe the coexistence of some countries that increased their reduction rate, some others with positive growth rates (especially for the male case), whilst most of the countries experience a slowdown in their decreasing rates.

The results of this initial descriptive analysis point to the existence of considerable variation in the evolution of the PYLL. These differences are summarized in Figures 1a and 1b, which reflect the time evolution of the variation coefficient for the female and the male case, respectively. As we can observe, the cross-sectional dispersion has clearly increased over time, being even higher for the male case than for the female. Furthermore, the dispersion is more marked in the last part of the time-series, which suggests that countries did not exit from the Great Recession in a similar way, with some of them suffering serious losses in the health levels of their inhabitants.

This heterogeneity implies an increment in health inequalities, making difficult the definition and the achievement of global health goals. This can be interpreted as the inexistence of convergence in the health status of the OECD countries, given that convergence implies that the dispersion must decrease. In fact, the results of the analysis shown in Figure 1 do not suggest the existence of σ-convergence. Rather, we should conclude that both male and female PYLL diverge. However, this is not the most appropriate method to determine convergence, given that we do not test this hypothesis directly. The following section presents the methodology that we will employ to that end.

I.2.2. Methodology

Convergence has been defined in the economic literature as a process where the dispersion of a variable reduces for a group of countries or regions. At the limit, when the cross-sectional variance is 0, all the components of this group show the same value of the variable. The interest in this type of analysis grew due to the seminal paper by Barro and Sala-i-Martin (1992), who focused their analysis on the per capita Gross Domestic Product (GDP). This paper was the seed of a very large literature, mainly focused on the use of the β- and σ-convergence concepts. However, the criticism of the use of the β-convergence notion made by Quah (1993) and Friedman (1992), based on the results of Galton (1877), suggested the use of alternative methods to analyse convergence. To that end, Carlino and Mills (1993, 1996) and Bernard and Durlauf (1995) developed a somewhat different approach, based on the use of unit root test statistics to test the time series properties of the ratio of the per capita GDP (or an alternative socioeconomic measure) of two geographical units (i.e. countries, regions, provinces). The presence of a unit root in the above-mentioned ratio was considered as evidence against convergence.

However, none of these papers develop or use a statistic that focuses on testing the null hypothesis of convergence. This problem is considered in Phillips and Sul (2007, 2009), PS hereafter, who designed a very popular statistic that has been extensively employed to test for convergence. Due to its capacity to analyse the existence of disparities in the evolution of these variables, it comes as no surprise that this statistic has been recently applied to the convergence analysis of some health variables. For instance, Panopoulou and Pantelidis (2013) and Clemente *et al.* (2019a, 2020) studied health care expenditure in the United States and Clemente *et al.* (2019b) studied the case of Spanish regional health care expenditure. Closely related to this, Duncan and Toledo (2019), Kasman and Kasman (2020) and González-Álvarez *et al.* (2020) analysed the international evolution of obesity indexes. Finally, Panopoulou and Pantelidis (2012) examined some health outcomes for a group of OECD countries, whilst Christopoulos and Eleftheriou (2020a) focused on the potential years of life lost in the United States. As we can observe, the use of this methodology is becoming a very useful tool to determine the existence of different patterns of behaviour of some health variables. Therefore, it seems appropriate to apply it to the present case.

The methodology is defined as follows. Let us consider that X_{it} represents the log of the potential years of life lost, with i=1, 2, …, 33 (the considered OECD countries) and t= 1990, …, 2017. This variable can be decomposed as $X_{it} = \delta_{it}\, \mu_t$, where μ_t is the single common component and δ_{it} is the time-varying factor loading coefficient that measures the idiosyncratic distance between the common trend components μ_t and X_{it}. PS suggest testing for convergence by analysing whether δ_{it} converges for some δ. To do so, they first define the relative transition parameter, as follows:

$$h_{it} = \frac{X_{it}}{N^{-1}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}} \qquad (1)$$

This variable describes the transition path for the i-th country relative to the panel average. In the presence of convergence, δ_{it} converges towards δ and, therefore, h_{it} should converge towards 1, while its cross-sectional variation, H_{it}.

It is defined as follows:

$$H_t = N^{-1} \sum_{i=1}^{N}(h_{it} - 1)^2 \rightarrow 0, as\ T \rightarrow \infty \quad (2)$$

should go to 0 when T goes towards infinity. Then, PS test for convergence by estimating the following equation:

$$log \frac{H_1}{H_t} - 2log[\log(t)] = \alpha + \beta \log(t) + u_t, t = T_o, \dots, T \quad (3)$$

with $T_o = [rT]$, and r=0.3, and u_t being the perturbation of the model. Equation (3) is commonly known as the log-t regression. The null hypothesis of convergence is rejected whenever parameter β is lower than 0. PS suggest estimating model (3) by methods that take into account the possible presence of autocorrelation and heteroscedasticity and, later, building the corresponding t-statistic to test the null hypothesis β=0. The use of these robust methods ensures that this t-ratio converges towards a standard N(0,1) distribution and, therefore, we will reject the null hypothesis of convergence whenever this t-statistic takes values lower than -1.65.

If we reject convergence, PS propose the following robust clustering algorithm for identifying clubs in a panel:

i. Order the N countries according to their final values of the variable under analysis (PYLL in our case).
ii. Form the core group. This core group consists of the k countries that maximize the value of the convergence t-statistic, subject to the restriction that it is greater than -1.65 and that 2<=k<N.
iii. Add one country at a time of the remaining countries to the core group, and re-estimate model (3) for each formation. Use the t-statistic to decide whether a country should join the core group.
iv. Repeat steps (ii)–(iii) iteratively and stop when clubs can no longer be formed. If the last group does not have a convergence pattern, conclude that its members diverge.
v. More details on this procedure can be found in Du (2017).

PS recommend performing club merging tests after running the algorithm using equation (3) in order to avoid an over-estimation of the number of clubs. Finally, we have followed the suggestion of PS and extracted the trend components of the series by filtering them using the Hodrick and Prescott (1997) filter, applying the standard value λ=400.

I.3. Results

I.3.1. Convergence

The results of the of the Phillips-Sul methodology are presented in Table 2. Panel I shows that the null hypothesis of convergence is rejected for both male and female PYLL. This implies that this health indicator presents great differences in its evolution, such that we cannot observe a common behaviour across the considered sample. However, it is still possible that some countries show similarities and, consequently, the existence of some convergence clubs. We should note that a convergence club is a statistically created grouping to capture the intrinsic PYLL trajectory shared by several countries, as Liou *et al.* (2020) state. The use of the clustering algorithm of PS allows us to estimate the existence of 4 convergence clubs for both female and male cases, as Panel II reflects. It is relevant to recall the ordering nature of these estimated clubs to better interpret them. Then, we should note that Club 1 includes the countries with the highest values of PYLL. By contrast, Club 4 is made up of the countries that perform best, in the sense that they show the lowest PYLL values. Panel III of Table 2 shows the results of the PS club merger tests performed to avoid overestimating the number of clubs, but the results indicate that there is no convergence between adjacent clubs, so the final number of estimated clubs remains unaltered.

To make the interpretation of the results easier, Figures 2a and 2b present the maps with the estimated clubs for the female and the male case, respectively. If we analyse the composition of these clubs, we can observe that the countries included in Club 1 are Brazil, Mexico and the United States for the female case, and Brazil, Hungary and Mexico for the male case. Similarly, Club 2 includes Canada, three Latin American countries (Chile, Colombia and Costa Rica) and three European countries (Hungary, Poland and United Kingdom) for the female case. For the male case, the composition slightly varies, in that Club 2 includes the United States, the three Latin American countries (Chile, Colombia and Costa Rica) and three European countries (Czech Republic, Greece and

Poland). Club 3 and Club 4 are composed of European countries and the Asian and Oceanic countries (Korea, Japan and Australia). We can see that Australia, Belgium, France and Germany are included in Club 3 for both cases, whilst Ireland, Israel, Italy, Korea, Luxembourg, Norway, Spain, Sweden and Switzerland always belong to Club 4.

As we have seen, there are some differences in the composition of the estimated convergence clubs when comparing the female and the male case. To analyse whether the differences are significant, we have constructed the variables CF_i and CM_i, which take the value m if the i-th country is included in the m-th estimated club, with m=1, 2, 3, 4 and CF and CM reflecting the female and the male case, respectively. Later, we have calculated the statistics proposed by Kruskal and Wallis (1952) and Van der Waerden (1953) for these variables in order to test for the equality of the median of the samples. These statistics take the values 0.22 and 0.27, respectively. They asymptotically follow a χ^2 of n-1 degrees of freedom, with n being the number of variables considered (2 in the present case). Then, we should conclude that the differences are not significant and the cluster algorithm provides similar results for the two gender cases.

If we now focus on some particularly interesting countries, we find that the case of the United States is noteworthy, since this country is included in the estimated clubs with the largest values of PYLL. The case of Germany is also noticeable given that it is never included in the best estimated club (Club 4), whilst this country belongs to Club 3 for both genders. By contrast, we observe that the Mediterranean countries such as Spain and Italy perform as well as Scandinavian countries such as Denmark, Iceland, Norway and Sweden.

Figures 3a and 3b reflect the evolution of average values of the PYLL for the different estimated clubs. It is observed that the evolution of the PYLL clearly declines for all the cases. We can also appreciate some gender and time differences. The gender comparison shows that the decline in the PYLL is slightly greater for the male case than for the female case. For instance, the average growth rate of Club 1 is -1.7% and -1.4% for the male and the female case, respectively. Similarly, these growth ratios are -2.9% and -2.5% for Club 4.

If we now focus on the time evolution, we can also draw some interesting insights. To that end, we can split the sample into two segments, 1990-2008 and 2008-2017, in order to capture the effect of the Great Recession on the evolution of the PYLL. For both the female and the male cases, we can observe that the Great Recession slowed down the process of improvement in the health indicator. For instance, the average growth rates of Club 1 for the periods pre and post Great Recession are -1.7% and -0.8%, for the female case, and -2.2% and -1.3%, for the male case. Similarly, the growth rates for the estimated Club 4 are -3.1% and -2.1%, for the female case, and -3.6% and -2.6%, for the male case. The values for the Clubs 2 and 3 are qualitatively similar, although slightly lower in quantitative terms.

We can also draw some insights by analysing the evolution of the estimation of the parameter β in (3). Figure 4 shows its estimated values when the sample goes from 1990 to k, with k=2004-2017. As we can appreciate, the estimated value remains almost unaltered until the onset of the Great Recession. However, it clearly decreases after 2010. This simple analysis, in the sense that it is just based on the evolution of the log t-ratio statistic, is quite useful to show that disparities did not cease growing after that period, although cannot help us to understand why this has occurred. In any event, it clearly suggests the existence of an effect of the Great Recession on the evolution of the health outcomes, and quite probably on some other socioeconomic variables, supporting the existence of a strong relationship between economics and health.

I.3.2. Factors driving Club formation

The previous section has shown how OECD countries do not exhibit similar levels of PYLL. Rather, we have estimated the existence of 4 convergence clubs for the female and the male case. It is sensible now to investigate which factors may drive the formation of these estimated clubs. To that end, we have estimated an ordered logit model. This type of model has been selected because the dependent variables are ordinal and ranked in descending order according to the different steady states. The initial model specification is as follows:

$$y_i = x_i'\beta + u_i \qquad (i=1, \ldots, 33) \tag{4}$$

where the dependent variable y_i may have various possible outcomes, each of them related to the number of clubs that the PS methodology has estimated. Then, $y_i = m$ if the i-th country is included in the m-th estimated club, with $m = 1, 2, 3, 4$. On the other hand, the vector of independent variables x_i' reflects the different factors that could explain the drivers of the estimated clubs.

As a previous step to the estimation of the ordered logit, we have considered a set of general socio-economic variables that are commonly used in the literature as possible explanatory variables in the model. For this purpose, we have followed the papers of Lynch *et al.* (2004), López-Casasnovas and Soley-Bori (2014), James (2015) and Gavurova *et al.* (2020), amongst some others, where the determinants of health outcomes are analysed.

The set of potential explanatory variables is presented in Table 3, whilst their definition and the source of the data are reflected in the Appendix I. Table 3 also includes the average values of these variables for the different estimated clubs, with these averages based on the use of the last observed value of each explanatory variable. In what follows, we present these variables and analyse the average values in order to better understand their powers of discrimination.

The first group of variables is composed of some socioeconomic indicators. In this regard, we should note that the results of some previous studies, such as those of Varbanova and Beutels (2020) and Gavurova *et al.* (2020), reveal the importance of variables such as the per capita Gross Domestic Product (GDP), the Gini index, the Human Capital index and the unemployment rate. The results shown in Table 3 confirm this, and we can observe a clear relationship between economy and health in such a way that the worse the economic conditions, the worse the health outcomes. To see this, we should simply note that the average Gini index indicates that Clubs with the highest premature deaths show the highest degree of income inequality among the population. Similarly, the per capita GDP and the Human Capital Index have an inverse relationship with PYLL. The higher the economic and social development, the lower the premature deaths for both female and male populations (López-Casasnovas and Soley-Bori, 2014).

The unemployment ratio, however, does not provide any clear discrimination between clubs. A possible explanation is given by the fact that unemployment, especially structural unemployment, is influenced by institutional factors, such as the performance of trade unions and employers' organizations in terms of collective bargaining and dismissals (Van Gool and Pearson, 2014).

Another interesting group of variables is that which represents the status of the health system of each country. Then, following Panopoulou and Pantelidis (2012), Park and Nam (2019) and González-Álvarez *et al.* (2020), we considered variables such as the degree of population immunization, life expectancy, mortality, the prevalence of some diseases and per capita health expenditure.

Table 3 shows that measles immunization and polio immunization are directly related to premature mortality (the higher the immunization rate of the population, the more probable the country will be included in clubs with the lowest values of PYLL). We also observed that measles immunization discriminates better against clubs than polio immunization. By contrast, mortality caused by cardiovascular disease, cancer or diabetes has a different sign, but a similar interpretation, given that the higher the average values of these variables, the more probable the country will be included in the clubs with the highest premature mortality. Both results are expected, especially if we take into account the results of Meslé *et al.* (2002) and Vallin and Meslé (2004) who consider that the capacity of countries to prevent mortality caused by these diseases (via the adoption of new technologies) is key to understanding the differences in mortality between countries.

The analysis of the means of the prevalence of diabetes, anemia and overweight persons indicates that as the prevalence of these diseases decreases, premature mortality is lower (we are in better clubs). It has to be pointed out that overweight discriminates less for males than for females; however, anemia and diabetes discriminate equally for both.

By contrast, we cannot observe a linear link between Current Health Expenditure and PYLL. Rather, we can observe that, for the female population, the average of this variable in Club 1 is the highest, then it decreases between Club 1 and Club 2, and increases again between Club 2 and Club 3, before decreasing again in Club 4. The behaviour of this variable for the male case is the opposite: the Current Health Expenditure increases for the first Clubs as we move from the first Club to the third Club but decreases again in Club 4 (Table 3).

Finally, we have also considered some variables that can offer a view on the political stability of the country, as Mackenbach *et al.* (2013), Zare *et al.* (2015) and Woolf and Schoomaker (2019) have done. Following these papers, we have used the government effectiveness, control of corruption and voice accountability variables.

The inclusion of some governance variables is relevant in order to reveal the influence of institutions on healthcare. In our case, the results of Table 3 suggest that the lower the control of corruption, the higher the premature mortality. However, the higher the effectiveness of governance, the lower the premature mortality. Similarly, we observe that the greater the degree of participation of a country's citizens in the election of their government, as well as freedom of expression, freedom of association and freedom of the media, the lower the premature mortality of its inhabitants.

Finally, we consider that the environmental policy may clearly influence the health of the citizens of a country. Consequently, our set of the potential drives should include some environmental variables. Following the results of Leksell and Rabl (2001) and Lelieveld *et al.* (2015) or Samoli *et al.* (2019), who have highlighted the importance of the impact of air pollution on health, we have additionally considered carbon dioxide damage and greenhouse gas emissions.

The results of Table 3 are quite useful for providing solid evidence of the link between environment and health. For both males and females, the discriminatory power of this variable is noticeable, and those countries included in the clubs with the lowest PYLL values exhibit the lowest levels of CO_2 emissions. This result is better understood if we take into account the connection between mortality caused by cardiovascular disease and air pollution. According to the World Health Organisation (WHO, 2021), 9 out of 10 people are exposed to levels of air pollution that put them at increased risk of cardiovascular disease. These types of diseases are the leading cause of death worldwide, claiming an estimated 17.9 million lives each year. By contrast, greenhouse gas emissions seem to exhibit a lower predictive capacity, as can be observed in Table 3.

Once we have presented the group of potential explanatory variables, we should employ them to estimate the best possible logit model. To that end, we have first pre-selected those variables that can help us to discriminate the inclusion of a country in the different estimated clubs based on the average values included in Table 3. Later, we have used them in a general-to-particular strategy, removing the non-significant variables. The final estimated model is presented in Table 4.

The male model includes the following variables: The Gini index, per capita GDP, measles immunization, mortality from cardiovascular diseases, cancer or diabetes, and carbon dioxide damage. The female model is somewhat different. It does not include per capita GDP and carbon dioxide damage but does include health expenditure. The explanatory power of both models is high: the female model correctly classifies 76% of the countries, whilst this figure for the male model is even slightly higher (79%).

The results of the ordered logit estimation show that the Gini index for both female and male has a negative effect on premature deaths. Then, if the level of inequality increases, there is a greater probability of being in the worst club and therefore that the population loses more potential years of life. The importance of inequality is greater for the female model, indicating a different incidence in the effect of inequality on premature deaths depending on the gender considered. This result is better understood if we take into account that, in spite of considering developed countries, females still have, on average, less access to education, earn less than males and enjoy less economic independence in these countries. This translates into females having fewer health resources and less access to health care (Arber and Thomas, 2001; Bartley, 2004; Kawachi and Kennedy, 1999; Kawachi *et al.*, 1999), and the gender gap still exists in this respect.

By contrast, we can observe that the per capita GDP is positively related to the creation of male clubs and we can conclude that the economic development of countries allows the male population to lose fewer potential years of life. This result is consistent with several previous studies which showed that countries' development is positively related to national levels of health (Lynch *et al.*, 2004; Torre and Myrskylä, 2014; Christopoulos and Eleftheriou, 2020a). Our results indicate that greater availability of resources and improvements in lifestyle and nutrition, as Ashraf *et al.* (2008) note, translates into reduced premature mortality and increased life expectancy.

The negative coefficient that accompanies Current Health Expenditure in the female estimation confirms the results obtained from our initial descriptive analysis. Then, as current health expenditure increases, there is a greater possibility of being in a worse club and therefore that the female population, in this case, loses more potential years of life. This variable is relevant and can explain why some countries are placed in unexpected clubs, as in the case of the United States. It is interesting to note that OECD countries have the highest health expenditure in the world (Mujtaba and Shahzad, 2021), so one would expect that they should also show the best health outcomes. However, the negative sign suggests that this is not necessarily true, opening the door to using efficiency as a key factor in this regard, as we will discuss later.

We can also observe the importance of the variables that measure the health status of the country. In particular, measles immunization appears in the final estimated model. In this regard, we should note that vaccination against diseases mainly affects the first years of life, having a positive and long-term effect on the life expectancy of the population and a negative effect on infant mortality (Park and Nam, 2019). According to the World Health Organization (WHO, 2021), immunization is a global health and development success story. Vaccines are available to prevent more than 20 life-threatening diseases, helping people of all ages to live longer, healthier lives. For example, vaccination against diphtheria, tetanus, pertussis and measles prevents between two and three million child deaths each year, and many more future deaths in older age groups (Duclos *et al.*,2009). Our results show that measles immunization has a positive coefficient for both males and females, and premature deaths are reduced when the percentage of the population vaccinated against measles increases. Measles immunization is the type of vaccination that allows us to analyse total vaccination coverage, since it is a prototypical health service.

Mortality due to cardiovascular disease, cancer or diabetes has a direct effect on the increase in premature deaths, as already indicated by the averages. It is noteworthy that the environmental variable is only relevant for the male estimate and with a negative effect on clubs. This result is supported by the research of Abbey *et al.* (1999) who found a positive correlation of air pollution with mortality for men, but not for women. These results may be due to limitations in the way data on air pollution deaths are measured, as the World Health Organization (WHO) uses national estimates of solid fuel use to calculate indoor air pollution deaths that do not consider possible differential risks for women within societies or within the household (Austin and Mejia, 2017). However, some studies along these lines also estimate that more men die from air pollution than women (Lim *et al.*, 2012; WHO, 2021).

I.4. Discussion

The results we have obtained lead us to draw very useful insights. First, we should note that the use of the PS methodology has allowed us to reject the convergence hypothesis, which statistically confirms the existence of different patterns of behaviour. Moreover, we can also observe that this disparity has grown since 2008. Then, the supra institutions such as the United Nations or the European Union should consider these disparities when setting their goals.

We have subsequently seen that we can group countries according to their PYLL evolution. The analysis of the forces that create the estimated clubs also produces some interesting implications. If we begin by considering the effect of per capita GDP on the creation of the estimated clubs, we can observe that this variable has a positive effect on the probability of being included in the club with the lowest premature male mortality. Previous researches have already pointed out that the higher the economic development, the more advanced the welfare state of a country. However, Widding-Havneraas and Pedersen (2020) and Asiskovitch (2010) show that a higher wealth status does not necessarily lead to improvements in people's life expectancy if this is not accompanied by a more equitable distribution of material resources that directly or indirectly improve health. Low-income individuals appear to be more vulnerable to health limitations (López-Casasnovas and Soley-Bori, 2014), so reducing income inequality would improve the health of the most disadvantaged population and help reduce health inequalities (Bremberg, 2017).

In connection with this point, we should note that the United States is the country where income inequality is most closely related to population health because the composition of United States health spending is mainly from private sources (Lynch *et al.,* 2004). An examination of how the public-private composition of health spending affects health outcomes shows that when health care is financed more by public spending, it is associated with lower rates of premature mortality for both genders (Or, 2000).

Another interesting insight is that our estimations show that health care expenditure only appears in the female model. Furthermore, this estimated parameter takes a negative value, which suggests that increments in the level of health care expenditure raise the probability of a country being included in Club 1. In order to explain this (apparently) counterintuitive result, we should consider the existence of decreasing returns of health care spending in developed countries, as Nixon and Ulmann (2006) point out. These authors suggest the presence of a saturation point for health spending in developed countries, in such a way that increments in the levels of health care expenditure do not generate proportional variations in the health of the population. This is also supported by the results of Poullier *et al.* (2002), Potrafke (2010) and Chansarn (2010), who note that health care expenditure in high-income countries brings only marginal improvements in life expectancy. The existence of a problem of efficiency in the use of health expenditure is also concluded in López-Casasnovas and Soley-Bori (2014), Ravangard *et al.* (2014), Blázquez-Fernández *et al*. (2017), Linden and Ray (2017), Costa (2021) and Costa *et al.* (2021). The results of Christopoulos and Eleftheriou (2020b) are useful in this regard, showing that the marginal benefit of every additional dollar spent by the OECD countries on healthcare is pretty close to 0.

The presence of an environmental variable also deserves a comment, given that this provides additional evidence of the direct connection between health and the environment. We should note that, according to WHO results, ambient air pollution is responsible for 4.2 million premature deaths each year as a result of exposure to fine particulate matter. To better understand the effect of this “silent killer”, to use the denomination employed in Austin and Mejia (2017) and Zhang (2017), we should note that air pollution is estimated to cause 6-9 million premature deaths per year and will cost 1% of OECD countries' GDP by 2060 (OECD, 2021). Therefore, controlling pollution is a key factor not only to achieve greener and more sustainable economic growth, but also to avoid unnecessary damage to people’s health.

Finally, we recognise that the estimation of the ordered logit model is not free of problems, mainly due to the scantiness of the sample, as Ogundimu *et al.* (2016) reflect. In spite of this, the combination of the results presented in Tables 3 and 4 are very helpful to identify which the most relevant factors are. We should also note that a causality analysis would be a good complement to the analysis carried out here, which would require the use of somewhat different econometric tools. Therefore, this is left for future research.

I.5. Conclusions

The aim of this paper has been to analyse the existence of disparities in the evolution of some international health indicators. For this purpose, we have selected the potential years of life lost variable, given that it can summarize the general health status of a society better than alternative indicators such as life expectancy or the mortality rate. The considered database covers the period 1990-2017 and includes information of 33 OECD countries, with data being disaggregated by gender.

We have employed the methodology designed by Phillips and Sul (2007, 2009). Its use has allowed us to reject the null hypothesis of convergence for the female and the male case. This implies that the 33 OECD countries do not have a common pattern of behaviour in terms of potential years of life lost. Subsequently, we have analysed whether some convergence clubs may exist, by applying the clustering algorithm proposed by Phillips and Sul. We have estimated the existence of 4 convergence clubs that exhibit small and non-statistically significant gender differences. The analysis of the time evolution of these estimated clubs shows that the PYLL has declined for the sample, although the speed of this decline has clearly slowed down since the Great Recession.

We have also analysed the drivers of club formation. The explanatory variables finally included in our estimated models are the Gini index, current health expenditure, per capita GDP, measles immunization, mortality from cardiovascular disease, cancer or diabetes, and carbon dioxide damage. We find gender differences in the estimation of the model: for females, the Gini index, current health expenditure, measles immunization and mortality from cardiovascular disease, cancer or diabetes are important; while for males the Gini index, per capita GDP, immunization rates, mortality from cardiovascular disease, cancer or diabetes, and carbon dioxide damage are relevant.

Per capita GDP and measles immunization have a positive effect on potential years of life lost. The economic development of a country is positively related to good national health levels, while vaccination against diseases that mainly affect the first years of life has a positive and long-term effect on the life expectancy of the population. Thus, growth must be accompanied by public health policies that maintain adequate levels of health coverage and consider the health benefits derived from advances in vaccines.

On the other hand, the Gini index, mortality due to cardiovascular disease, cancer or diabetes, per capita current health expenditure and the cost of damage due to carbon dioxide emissions have a negative effect on premature mortality. Health inequalities arise from unequal income distribution and discrepancies related to access to health care, education, work and living conditions. The United States is the country where income inequality is most related to the health of the population; even though current United States healthcare spending has increased in recent years, its impact on improving the population's health is not apparent.

To reduce the incidence of premature mortality from cardiovascular disease, cancer or diabetes, the development of cost-effective, accessible and equitable healthcare innovations is necessary for their management. Finally, the cost of damage due to carbon dioxide emissions has a negative effect on the health of the population. In view of the results and for future air pollution scenarios, public agencies should choose to further restrict air pollution, as it directly affects the health of the population.

The results obtained are relevant for future health scenarios, especially for countries where air pollution continues to increase and where suitable emission levels are not expected to be reached to prevent the population from developing cardiorespiratory diseases. The development of comprehensive strategies, cost-effective health innovations and equitable management, such as improving the capacity of health systems to care for patients with cardiovascular issues and monitoring disease patterns and trends, is needed to reduce the incidence, morbidity, and mortality of the disease. Likewise, to avoid the adverse effects of air pollution, governments need to develop policies that support effective environmental actions as a key aspect of future health improvement. Governments should consider that to reduce premature mortality, growth must be accompanied by reductions in health and economic inequality.

I.6. Figures and tables

Table 1. PYLL descriptive analysis (1990-2017)

	Female					Male				
	min	**max**	**90-17**	**90-08**	**08-17**	**min**	**max**	**90-17**	**90-08**	**08-17**
Australia	2,608	4,516	-2.0%	-2.4%	-1.3%	4,415	8,367	-2.3%	-2.7%	-1.6%
Austria	2,606	4,829	-2.3%	-2.7%	-1.5%	4,736	9,948	-2.7%	-2.9%	-2.4%
Belgium	2,960	4,894	-1.8%	-1.9%	-1.8%	5,035	9,229	-2.2%	-2.0%	-2.7%
Brazil	5,913	9,334	-1.7%	-1.8%	-1.5%	11,920	17,377	-1.4%	-1.5%	-1.2%
Canada	3,177	4,621	-1.4%	-1.5%	-1.0%	5,002	8,640	-1.9%	-2.4%	-0.9%
Chile	3,537	7,051	-2.5%	-3.0%	-1.6%	6,273	13,438	-2.8%	-3.1%	-2.2%
Colombia	4,402	8,066	-2.1%	-2.2%	-2.0%	8,267	17,057	-2.4%	-2.4%	-2.3%
Costa Rica	3,772	5,832	-1.4%	-2.1%	0.1%	6,790	9,404	-0.9%	-1.4%	0.3%
Czech Republic	3,083	6,455	-2.7%	-3.0%	-2.1%	6,506	14,699	-2.9%	-3.2%	-2.5%
Denmark	2,856	5,921	-2.7%	-2.4%	-3.2%	4,590	9,710	-2.7%	-2.4%	-3.4%
Finland	2,558	4,668	-2.1%	-2.2%	-1.9%	5,311	11,300	-2.8%	-2.4%	-3.4%
France	2,669	4,259	-1.7%	-1.7%	-1.7%	5,364	9,982	-2.3%	-2.3%	-2.2%
Germany	2,900	5,023	-2.0%	-2.5%	-1.0%	5,110	9,937	-2.4%	-2.9%	-1.6%
Greece	2,577	4,238	-1.8%	-2.6%	-0.2%	5,507	8,005	-1.3%	-1.4%	-1.2%
Hungary	4,517	8,707	-2.3%	-2.4%	-2.3%	9,547	20,292	-2.6%	-2.2%	-3.4%
Iceland	2,235	4,494	-2.5%	-3.0%	-1.4%	3,557	7,628	-2.2%	-3.4%	0.3%
Ireland	2,614	5,392	-2.6%	-2.5%	-3.0%	4,149	9,173	-2.9%	-2.5%	-3.6%
Israel	2,403	5,170	-2.8%	-3.2%	-1.9%	4,108	7,675	-2.2%	-2.1%	-2.5%
Italy	2,276	4,200	-2.2%	-2.5%	-1.5%	3,971	8,720	-2.8%	-3.0%	-2.4%
Japan	2,069	3,442	-1.9%	-1.7%	-2.2%	3,924	6,670	-1.9%	-1.6%	-2.6%
Korea	2,071	5,643	-3.6%	-3.4%	-3.9%	4,511	13,140	-3.8%	-3.7%	-3.8%
Luxembourg	1,944	5,362	-3.3%	-4.2%	-1.5%	3,562	10,725	-3.8%	-4.1%	-3.1%
Mexico	6,047	9,618	-1.7%	-2.1%	-0.8%	10,564	15,743	-1.1%	-1.9%	0.6%
Netherlands	2,857	4,413	-1.6%	-1.5%	-1.8%	4,073	7,779	-2.4%	-2.7%	-1.8%
Norway	2,369	4,367	-2.2%	-2.1%	-2.6%	3,747	8,529	-3.0%	-2.8%	-3.4%
Poland	3,729	7,228	-2.4%	-2.5%	-2.2%	9,197	17,599	-2.3%	-2.0%	-2.7%
Portugal	2,604	5,734	-2.9%	-3.2%	-2.2%	5,685	12,370	-2.7%	-2.8%	-2.5%
Slovenia	2,558	5,633	-2.5%	-2.8%	-1.8%	5,172	13,052	-3.2%	-2.9%	-3.7%
Spain	2,198	4,189	-2.3%	-2.6%	-1.8%	4,314	9,432	-2.9%	-2.7%	-3.1%
Sweden	2,465	4,148	-1.9%	-2.0%	-1.6%	3,931	7,322	-2.3%	-2.6%	-1.7%
Switzerland	2,138	4,200	-2.5%	-2.4%	-2.5%	3,614	8,544	-3.0%	-3.3%	-2.4%
U. Kingdom	3,190	5,208	-1.8%	-1.9%	-1.6%	5,027	8,760	-2.0%	-2.1%	-1.7%
United States	4,648	5,954	-0.7%	-1.1%	0.1%	7,758	11,271	-1.1%	-1.7%	0.1%

This table presents some descriptive statistics of the PYLL variable. Min and Max are the sample minimum and maximum values, respectively, whilst the columns 90-17, 90-08 and 08-17 show the average growth rate for these periods, respectively.

Table 2: Testing for convergence for PYLL

	Female		Male	
Panel I: Testing for convergence	$\hat{\beta}$	Log t-ratio	$\hat{\beta}$	Log t-ratio
	-10.442	-829.828*	-10.421	-876.720*
Panel II: Initial estimated Clubs	$\hat{\beta}$	Log t-ratio	$\hat{\beta}$	Log t-ratio
Club 1:	0.083	1.980	0.127	0.577
	Brazil; Mexico; United States		Brazil; Hungary; Mexico	
Club 2:	0.135	2.213	0.074	1.190
	Canada; Chile; Colombia; Costa Rica; Hungary; Poland; United Kingdom		Chile; Colombia; Costa Rica; Czech Republic; Greece; Poland; United States	
Club 3:	0.676	6.385	0.415	5.033
	Australia; Belgium; Czech Republic; Denmark; France; Germany; Greece; Netherlands		Australia; Austria; Belgium; Canada; Finland; France; Germany; Japan; Portugal; Slovenia; United Kingdom	
Club 4:	0.164	5.456	0.644	6.876
	Austria; Finland; Iceland; Ireland; Israel; Italy; Korea; Luxembourg; Japan; Norway; Portugal; Slovenia; Spain; Sweden; Switzerland		Denmark; Iceland; Ireland; Israel; Italy; Korea; Luxembourg; Netherlands; Norway; Spain; Sweden; Switzerland	
Panel III: Club merging analysis	$\hat{\beta}$	Log t-ratio	$\hat{\beta}$	Log t-ratio
Club 1+2	-0.685	-122.655*	-0.504	-28.262*
Club 2+3	-0.296	-7.839*	-0.607	-50.400*
Club 3+4	-0.482	-11.688*	-0.276	-7.505*

The estimated β and the Log t-ratio are obtained from the estimation of equation (3). '*' Denotes statistical significance at the 5% level, rejecting the null hypothesis of convergence.

Table 3. Average values of factors driving Club formation

	Female				Male			
	Club 1	**Club 2**	**Club 3**	**Club 4**	**Club 1**	**Club 2**	**Club 3**	**Club 4**
GDP per capita	31,424	30,198	46,933	53,558	21,282	30,683	45,890	58,423
Gini Index	44.50	39.59	30.23	31.53	43.10	38.03	31.61	31.85
Human capital Index	0.64	0.70	0.77	0.78	0.62	0.69	0.79	0.77
Unemployment	6.86	6.24	7.60	6.62	6.79	8.22	6.26	6.46
Immunization measles	86.33	93.86	95.25	95.60	88.67	94.57	94.36	95.50
Immunization polio	84.66	93.57	95.87	95.00	86.33	94.00	94.09	95.75
Mortality CVD, cancer, or diabetes	15.63	14.59	11.64	9.79	18.43	14.34	10.70	9.63
Maternal mortality	37.33	22.00	5.12	4.86	35.00	21.42	6.45	4.50
Diabetes prevalence	11.56	7.08	6.35	6.12	10.26	7.67	6.40	6.00
Prevalence anemia	20.60	21.34	14.58	13.71	26.63	21.40	13.80	12.67
Prevalence overweight	63.10	61.62	59.76	54.34	61.00	62.07	56.46	56.27
Current Health Expenditure	10.68	8.17	9.70	9.01	7.29	8.92	10.00	8.98
Control corruption	-0.26	0.81	1.36	1.38	-0.45	0.52	1.55	1.48
Government effectiveness	0.41	0.77	1.34	1.45	0.07	0.64	1.50	1.49
Voice accountability	0.47	0.88	1.25	1.24	0.24	0.82	1.29	1.30
Greenhouse gas emissions	9.48	7.87	11.19	10.99	5.65	8.64	10.69	11.91
Carbon dioxide damage	1.01	1.04	0.79	0.58	1.11	1.16	0.70	0.52

This table presents the average values of the considered explanatory variables of each one of the estimated clubs. These average values are based on the use of the last observable value of the explanatory variables.

Table 4. Ordered logit estimation

	Female			Male		
	Coefficient	**t-Ratio**		**Coefficient**	**t-Ratio**	
Gini Index	-0.48	-4.20	***	-0.21	-2.01	**
Current Health Expenditure	-1.28	-3.73	***			
GDP per capita				0.0001252	2.79	***
Immunization measles	0.57	3.67	***	0.3061579	1.96	**
Mortality from CVD, cancer or diabetes	-1.87	-3.41	***	-1.65	-3.77	***
Carbon dioxide damage				-2.73	-1.89	*
Pseudo R^2	0.68			0.68		
Correctly predicted cases	76%			79%		

This table shows the results of the ordered logit estimation of equation (4). The dependent variable (y_i) takes the value m when the i-th country is included in the m-th estimated club, with m=1, 2, 3, 4. The t-ratios for testing the single significance of the parameters are robust to the presence of heteroscedasticity by using the Huber-White method, see White (1980) in this regard. '*' Denotes statistical significance at the 10% level. '**' at the 5% level. and '***' at the 1% level.

Figure 1: PYLL coefficient of variation

Figure 1a. Female

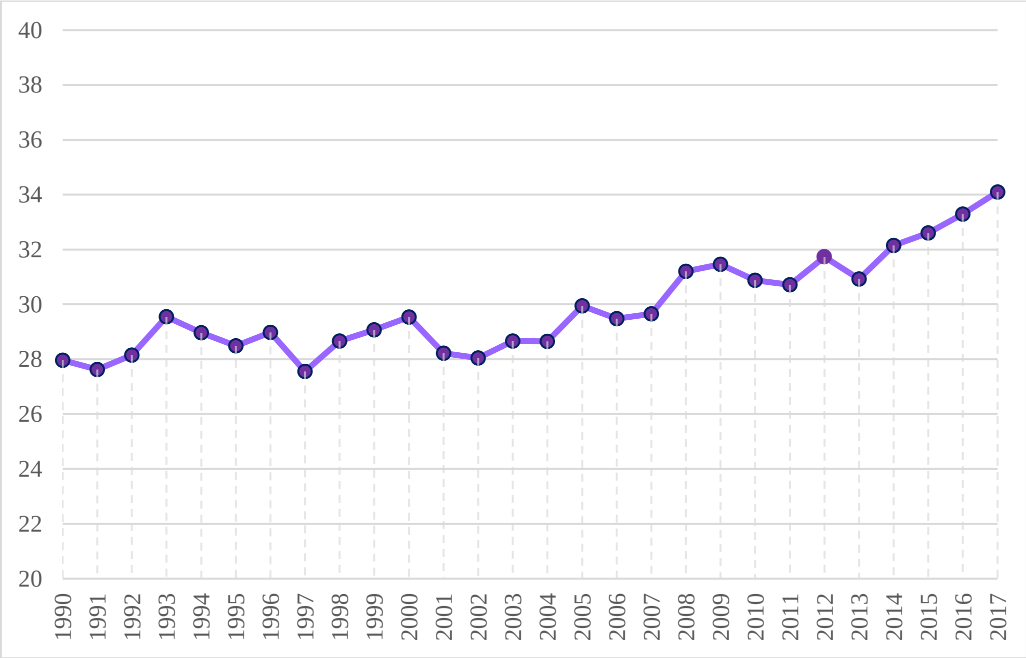
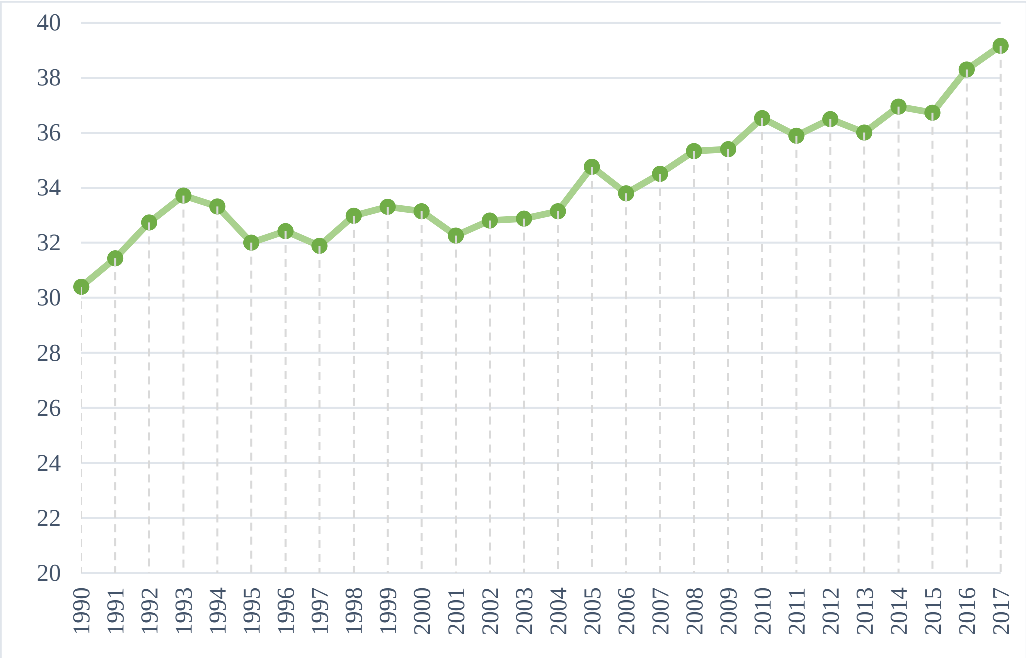


Figure 1b. Male



These figures present the evolution of the coefficient of variation of the female and male PYLL of the countries included in the sample for 1990-2017.

Figure 2: Geographical location of countries included in the estimated clubs

Figure 2a. Geographical location of countries included in the estimated clubs: Female case

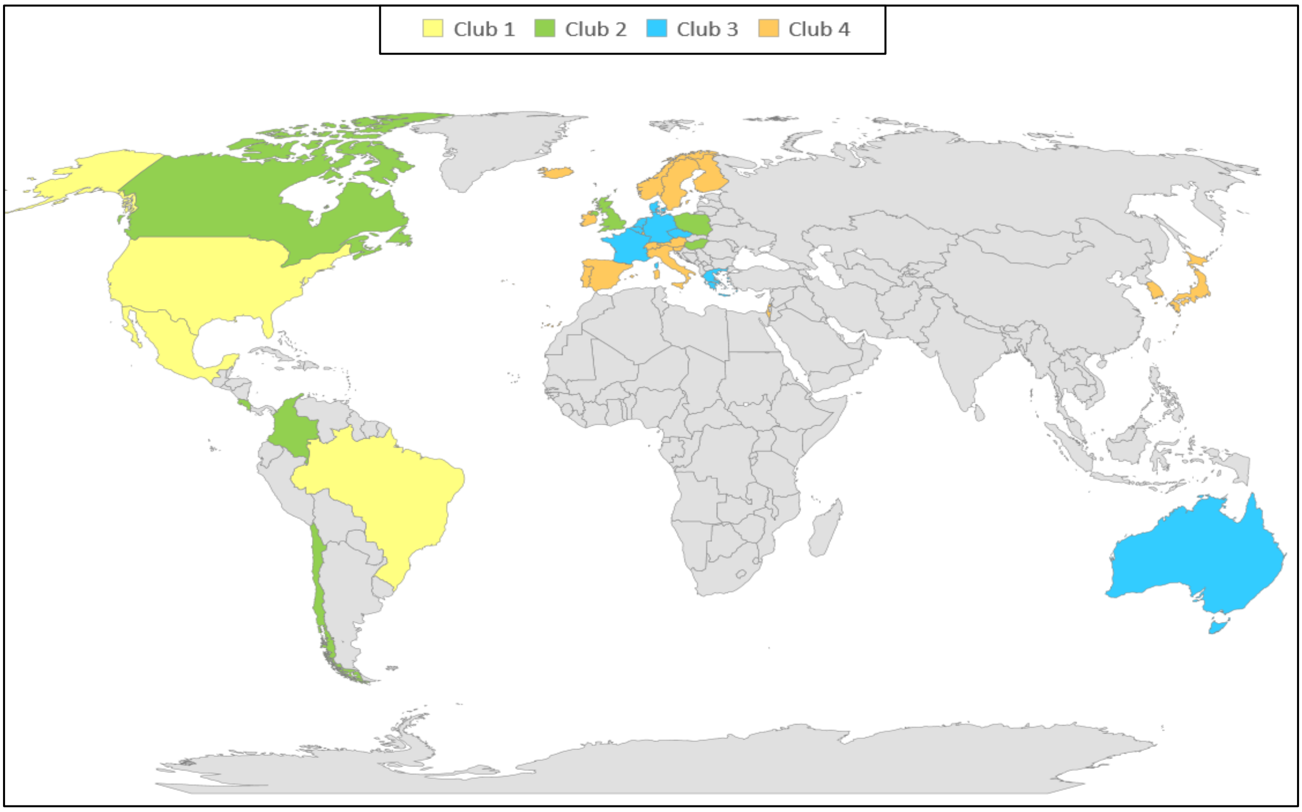


Figure 2b. Geographical location of countries included in the estimated clubs: Male case

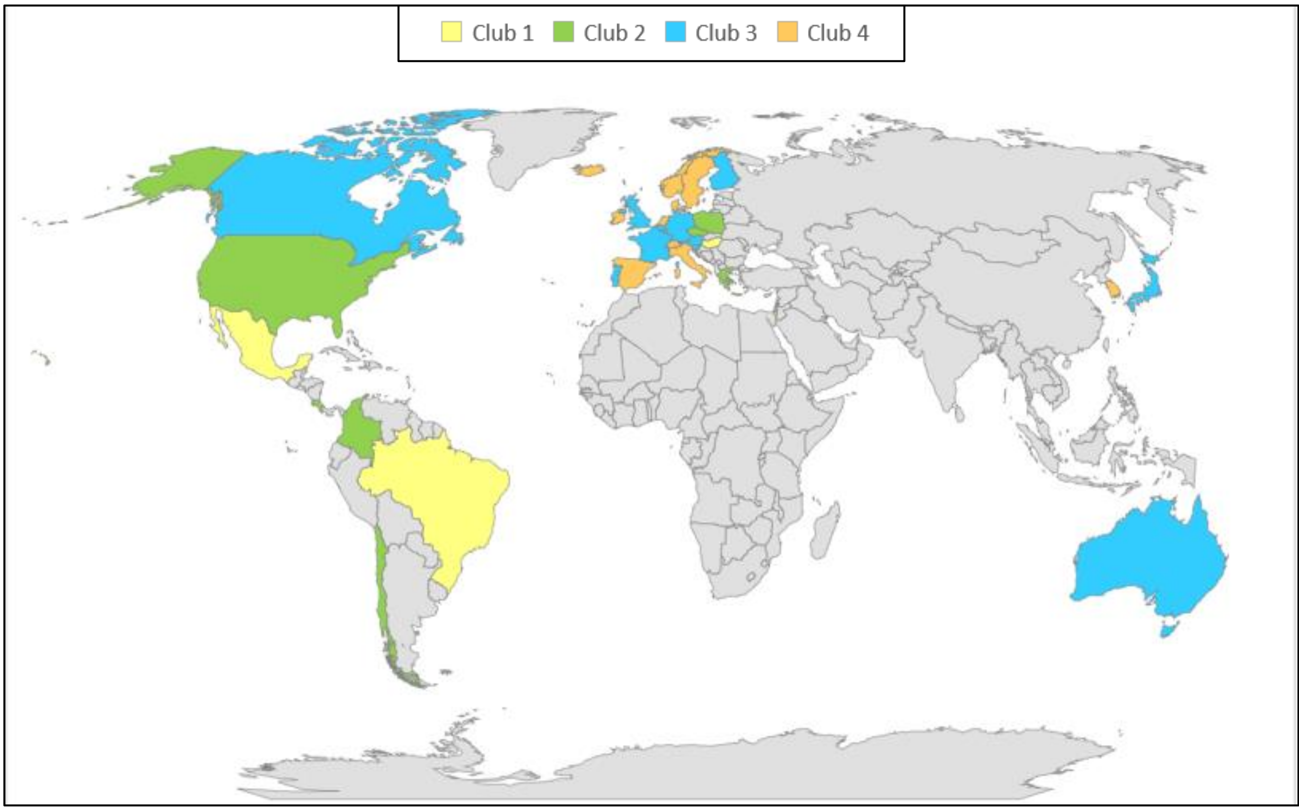


Figure 3: Average values of PYLL by estimated Clubs

Figure 3a. Female PYLL evolution

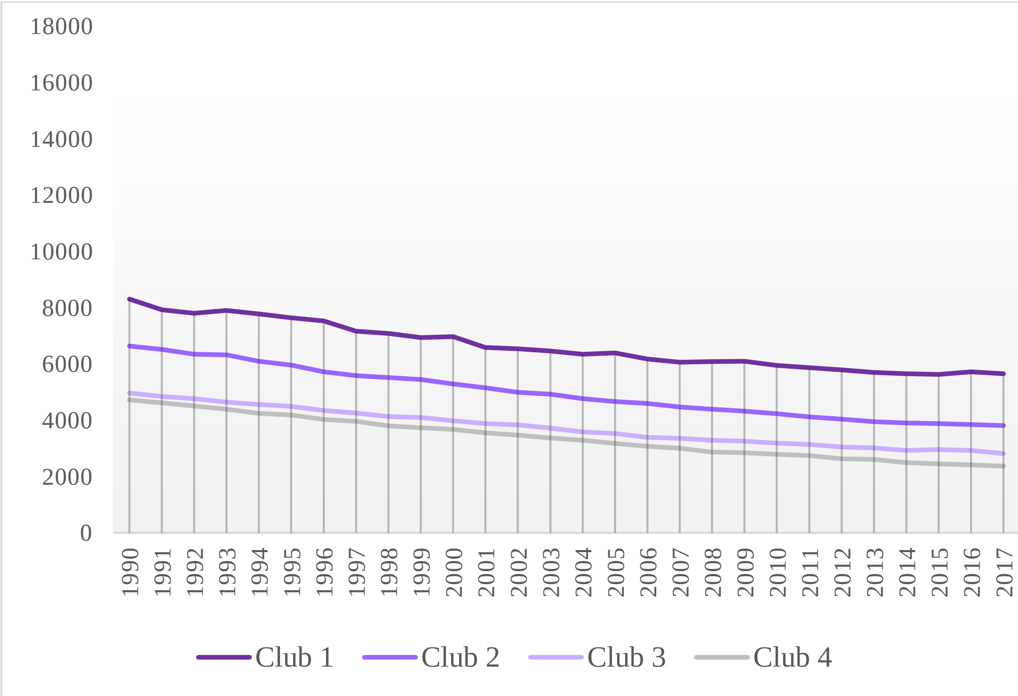
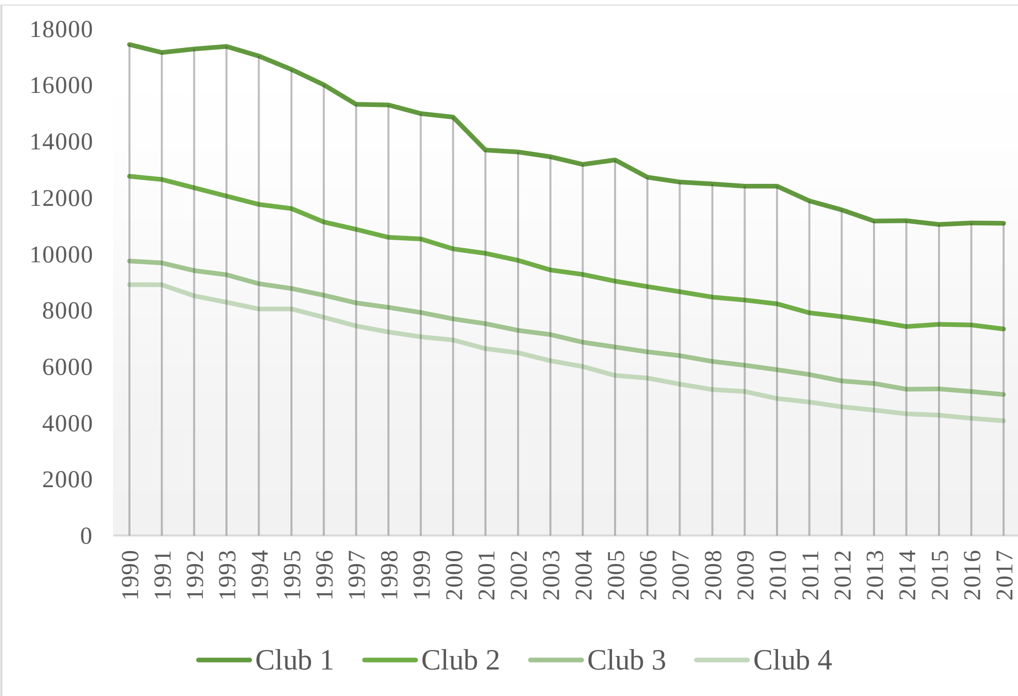
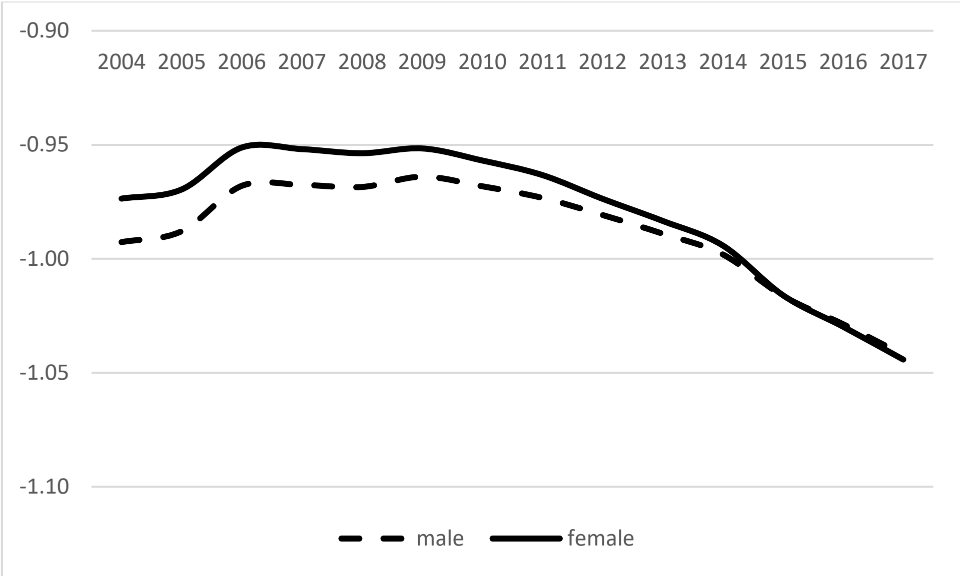


Figure 3b. Male PYLL evolution



These figures reflect the average values of the PYLL of different estimated clubs.

Figure 4. Log t-ratio evolution



This figure presents the values of the t-ratio for testing the null hypothesis $\beta = 0$ in (3) when this model is recursively estimated for the sample t=1990, …, k, where k=2004, 2005,…, 2017.

Chapter II: Health, economics and environmental degradation: is the relationship gender-neutral?

II.1. Introduction

The intricate network of interactions between health, economics, and environment constitutes the focus of modern discourse on sustainable development and public welfare, as López-Casasnovas and Soley-Bori (2014), Jakovljevic and Ogura (2016) and Manisalidis *et al.* (2020) have recently pointed out. In today's interconnected world, the ramifications of economic decisions extend far beyond financial metrics, reaching into environmental stability and human health. At the core of this nexus lies a dynamic relationship, where economic activities affect the environment and, in turn, impact human health, while environment influences economic outcomes and public health results. Recognizing and understanding these complex relationships is particularly important when designing effective policies and interventions that promote a harmonious balance between economic prosperity, environmental integrity, and population health.

Given the importance of the relationship between the above-mentioned variables, it comes as no surprise that we have witnessed a growing body of literature attempting to determine their connection. Initially, researchers considered primarily bivariate relationships. Seminal works by Preston (1975), Pritchett and Summers (1993), Deaton (2003) and Cutler *et al.* (2006) provide evidence of the positive relationship between economic growth and health, although recent studies have shown that crises can alter this relationship, as can be deduced from Ruhm (2000, 2016), Gerdtham and Ruhm (2006) and Tapia-Granados (2005, 2017). According to these papers, the evolution of the economy may have a long-run positive effect on population health, although the effects of recessions can modify this relationship in the short-run, as Stuckler *et al.* (2009), Basu *et al.* (2017), Huikari *et al.* (2019) and Dadgar and Norström (2022) conclude.

Studies examining the relationship between health expenditure and population health are also noteworthy, with the works of Hitiris and Posnett (1992), Nixon and Ulman (2006) standing out. Following Gallet and Doucouliagos (2017), it is clear that healthcare expenditure also positively affects health. However, the literature highlights that after the economic recession of 2008, public health expenditure experienced slower growth, and the resulting cuts in health services negatively affected equity, quality of care and health outcomes, as reported by Cylus *et al.* (2012).

The relationship between environmental degradation and health has been examined more extensively in recent years. The results of these analysis offer evidence that prolonged exposure to environmental degradation, particularly through air pollutants, can aggravate the general health of the population. In particular, there are health risks related to cardiovascular and respiratory diseases, as indicated by Mannucci *et al.* (2015).

In spite of the great interest of the previous literature, we can observe that these studies are based on a gender-neutral perspective. However, we should note that certain biological and behavioral differences prompt the questioning of this neutrality. Some papers have attempted to address this point, although the evidence remains limited and inconclusive. For instance, studies by Ivaschenko (2005) and Crémieux *et al.* (1999) analyze gender differences in the impact of health expenditure on health outcomes. The first concludes in favor of a female effect and the second observes a male effect. Similarly, Clougherty (2010) shows an increased risk of mortality and hospitalization for females. However, further research seems to be necessary to better understand the possible gender-specific effects of environmental degradation on population health, as recognized by Shin *et al.* (2021, 2022).

Against this background, this paper aims to provide a comprehensive understanding of how economic growth, health expenditure and environmental degradation affect population health, with special emphasis on potential gender differences. We should also allow for the possible presence of parameter instabilities in the relationship between these variables, in order to capture the possible effects that some recent events, such as the Great Recession, have had on the relationship.

The rest of the paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents the empirical results, whilst Section 4 outlines the discussion. Section 5 presents the main conclusions.

II.2. Data and methods

II.2.1. Data

The data sample includes 25 OECD countries, which face comparable economic and environmental challenges and dynamics. Specifically, to study the link between population health, economics, and environmental degradation, and to assess potential gender differences, we have considered the following variables. To measure the health status of the population of a country, we have selected the variable potential years of life lost (PYLL hereafter), and we have disaggregated it by gender: PYLLm for the male case and PYLLf for the female. We should note that alternative variables could have been selected, with life expectancy being a quite interesting option in this regard. However, we have chosen PYLL because it is a highly valuable measure of health outcomes, allowing a detailed understanding of the social impact caused by premature or young deaths, as indicated by Ledesma-Cuenca *et al.* (2022). This measure also adequately reflects the effectiveness of a specific country's health policies and helps to identify health disparities, as noted by Varbanova and Beutels (2020).

To explain the evolution of PYLL, we have considered various socioeconomic and environmental variables into our analysis. Per capita Carbon dioxide (CO_2) emissions are commonly used as a general indicator of environmental degradation, given that its accumulation and presence is linked to the release of other air pollutants, which may cause increased health risks. However, some alternative environmental degradation indicators may be used with population-weighted exposure to Particulate Matter 2.5 ($PM_{2.5}$) being the most widely used[1]. Other indicators are Nitrogen oxide (NO), Volatile organic compounds (VOCs), Carbon monoxide (CO), Methane gas (CH_4) and Nitrous oxide (N_2O) emissions. We will mostly focus on CO_2 and $PM_{2.5}$ across the paper, using the rest of the indicator to analyze the robustness of the results.

We have also included per capita GDP (GDP) as an economic measure, based on the study of Ouyang *et al.* (2019). Furthermore, per capita Health Expenditure (HEXP) has been considered as a metric for the health system's condition in each country, following the research of Owusu *et al.* (2021).

Most of the data have been collected from the OECD database, except those of CO_2, $PM_{2.5}$, N_2O and CH_4, which come from the World Bank database. The definitions of the different variables are presented in Appendix II. The sample comprises 25 OECD countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States, and the selected information covers 1990-2019.

Table 1 presents some descriptive statistics for the most relevant variables, with the rest being analyzed in Appendix III. We observe that PYLLm and PYLLf show a negative growth rate across the sample, although there is no homogeneous behavior across countries. For example, we observe that the United States and Greece show the smallest reduction in PYLLm, -1.1% and -1.2%, respectively. By contrast, South Korea and Norway show the largest reduction, with average growth rates of -3.7% and -3.1%, respectively. Similar results are observed for the female case. The countries with the lowest average growth rates in this case are France (-1.4%) and the United States (-0.8%), the latter being, again, the country that has reduced potential years of life lost the least during the period being considered. By contrast, South Korea and Portugal show the greatest reductions, with average rates of growth of -3.4% and -2.6%, respectively. We can also observe that European countries have experienced similar rates of decline.

To capture the possible effect of the Great Recession (GR in advance) on the evolution of our variables, we have split the sample into two periods: 1990-2008 and 2008-2019. Following with PYLLm and PYLLf, if we analyze the pre-GR sample, we can see that that average growth rates always take negative values. However, we can also observe that the range of variation is somewhat different between countries and between genders. For males, the average growth rates range from -3.7% in South Korea to -1.3% in Greece. If we consider the post-GR period (2008-2019), we can observe that the behavior is particularly heterogeneous. Although most countries experience a slowdown in their rates of decline, some countries show an increasing rate of decline, while others have growth rates close to zero or even positive, as in the case of the United States (0.1%). The results for females are slightly different. Before the GR, average growth rates ranged from -3.5% in South Korea to -1.1% in the United States. After the GR, most countries experienced a slowdown in their rates of decline, with Iceland and the United States showing the lowest decline rates (-0.4% and -0.2%, respectively).

The results for GDP indicate positive growth rates across the period from 1990 to 2019. During this time, the average growth rates ranged from 6.6% in Ireland to 2.6% in Japan. If we compare the period before and after the GR, we observe that all countries have seen a reduction in their average GDP growth rates. This reduction is especially severe in Greece, which fell from 4.8% to 0.0%, and in Norway (6.9% to 1.9%).

Positive growth rates are also observed for HEXP, following a pattern similar to GDP. We can see that average growth rates range from 3.5% (Iceland) to 8% (South Korea), when the total sample is analyzed. It can be observed that the rates in the pre-GR period are higher than those in the post-GR period, reflecting the impact of the GR on HEXP. Again, the most pronounced reductions are seen in Greece, which shifted from positive to negative growth rates (7.1% to -1.5%), and in Ireland, which decreased from 9.2% to 2.5%.

Finally, it is important to consider the evolution of the measures of environmental degradation included in our database. The average growth rates of CO_2 exhibit a quite heterogeneous behavior. We can observe that some countries have decreased their emissions for 1990-2019, such as Denmark and the United Kingdom (-2.3% and -2.2%, respectively), while others have increased them, such as South Korea (2.5%) and Portugal (0.2%). Comparing again the pre- and post-GR period, we observe the existence of two clearly differentiated patterns of behavior: countries with positive CO_2 growth rates in the pre-crisis period (e.g. South Korea with 3.4%, Portugal with 1.5% and Spain with 1.4%), and countries with negative growth rates (e.g. Czech Republic with -1.3%). These differences disappear after GR and almost all countries have decreased CO_2 emissions since 2008. Only South Korea (1.0%) maintains positive emission growth rates, although at a lower level than in the pre-crisis period.

Exposure to $PM_{2.5}$ mostly decreases over the whole sample, with all countries showing decreasing growth rates in the (-2%, -1%) range, except for South Korea (0.4%) and Japan (0.1%), as growth rates are positive. Comparing the pre- and post- GR periods, an overall decrease is observed for the countries in the post-recession period, except for the Asian economies, where exposure to $PM_{2.5}$ increases, rising from -0.61% to 1.3% in the case of Japan and from -0.4% to 1.6% in the case of South Korea.

This initial analysis gives us a first insight into how the Great Recession has had differentiated effects on the variables studied, leading to changes in the behaviour of countries in the aftermath of the event. A general reduction in environmental degradation has also been observed. However, the rate of reduction during the post-crisis period has slowed down compared to the previous period, opening the gate to parameter instabilities. To assess this point, as well as the possible presence of gender differences, an empirical analysis is required. The following section outlines the methodology we will use for this purpose.

II.2.2. Methodology

This section presents the methodological framework that we will employ throughout the paper. Given that our aim is to estimate the relationship between health outcomes, economic activity and environmental degradation, under the possible presence of breaks from a gender perspective, we should first analyze the time series properties of the variables. Once we have studied them, later we will discuss the most appropriate method for detecting the possible presence of breaks and, assuming they exist, we will estimate the relationship between these variables.

II.2.2.1. Testing for unit roots

The literature on panel data unit root tests has grown spectacularly since the previous century. Taking into account the seminal paper of Banerjee *et al.* (2004), it is habitual to begin this analysis by testing for cross-sectional independence in order to select the most appropriate type of statistic. The most popular statistic to that end is the one proposed in Pesaran (2015), which is defined as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \quad (1)$$

where T is the time period, N is the number of countries and $\hat{\rho}_{ij}$ is the pair-wise correlation coefficient.

Under the null hypothesis of cross-sectional independence, this statistic follows asymptotically a two-tailed normal distribution.

Alternatively, we should take into account the recent results of Juodis and Reese (2022) who show that the use of the CD statistics may be biased. Consequently, these authors propose a refinement of these statistics, referred to as CDw, where weighted cross-sectional covariances are used instead of cross-sectional correlations.

If we can reject the null hypothesis of cross-sectional independence, we can employ the statistic proposed in Pesaran (2007), which is obtained by the estimation of the following model:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \theta_i \bar{y}_{t-1} + \gamma_i \Delta \bar{y}_i + \varepsilon_{it} \qquad (2)$$

where $\bar{y}_{t-1}$ denotes the mean of the lagged levels; $\Delta \bar{y}_i$ is the mean of the first difference, whilst ε_{it} is the perturbation of the model, which is assumed to be white noise. Pesaran (2007) uses a modification of the above-mentioned statistics proposed in Im *et al.* (2003) given by the average of the individual cross-sectional Augmented Dickey-Fuller statistics (CADF) (Dickey and Fuller, 1979) from equation (2) in defining the cross-sectional augmented IPS (CIPS) to test the null hypothesis of a unit root:

$$CIPS = N^{-1} \sum_{t=1}^{N} t_i(N,T) \qquad (3)$$

Where $t_i(N,T)$ reflects the t statistic related to the Ordinary Least Squares (in advance OLS) estimation of the parameter β in the previous equation. Pesaran (2007) additionally proposed a finite samples refinement of these statistics, defined as follows:

$$CIPS^{*} = N^{-1} \sum_{t=1}^{N} t_i^{*}(N,T) \qquad (4)$$

With

$$t_i^*(N,T) = \begin{cases} K_1, t_i(N,T) \leq K_1 \\ t_i(N,T), K_1 < t_i(N,T) < K_2 \\ K_2, \;\; t_i(N,T) \geq K_2 \end{cases}$$

Therefore, the CIPS* is a truncated version of the CIPS, which removes the influence of extreme values. The parameters K_1 and K_2 are calculated by Pesaran (2007) using simulation methods.

The previous statistic corrects the possible presence of cross-sectional dependence by augmenting the equation (2) with the variables $\bar{y}_{t-1}$ and $\Delta\bar{y}_i$. However, this method works appropriately under the presence of a single common factor and, therefore, the existence of more common factors requires the use of alternative statistics. This is the case for those proposed by Bai and Carrion-i-Silvestre (2009) and Pesaran *et al.* (2013). Both offer statistics with adequate size and power properties under the presence of multiple unobserved common factors. However, we prefer the statistics proposed by Bai and Carrion-i-Silvestre (2009), given that their specification is much more flexible, allowing for the presence of multiple breaks in the trend function. Given that their omission may bias the unit root inference, and the presence of these breaks is a crucial hypothesis in this paper, we therefore opt for its use.

The Bai and Carrion-i-Silvestre (2009) are obtained as follows. First, these authors consider different specifications, including that which contains breaks in the trend polynomial. In the most general one, which is the one that we will consider, the deterministic component is obtained as follows:

$$D_{it} = \mu_i + \beta_i t + \sum_{j=1}^{m_i} \varphi_{ij} DU_{ijt} + \sum_{j=1}^{m_i} \gamma_{ij} DT_{ijt} \tag{5}$$

Where m_i reflects the number of breaks, DU_{ijt}=1 if $t > TB_{ij}$ and 0 otherwise, $DT_{ijt} = (t - TB_{ij})$ if $t > TB_{ij}$ and 0 otherwise, and TB_{ij} is the jth break point of the ith country, with $j = 1,2,\dots,m_i$.

The simplified test statistic is defined as follows:

$$Z^* = \sqrt{N \left\{\frac{[MSB^*(\lambda)] - \xi^*}{\zeta^{*2}}\right\}} \overset{As}{\rightarrow} N(0,1) \qquad (6)$$

With $MSB^*(\lambda) = N^{-1} \sum_{i=1}^{N} MSB_i^*(\lambda_i)$, $\xi^* = \sum_{i=1}^{N} \xi_i^*$, and $\zeta^{*2} = \sum_{i=1}^{N} \zeta^{*2}$. $MSB^*(\lambda)$ is the Sargan and Bhargava (1983) and Stock (1999) statistic for each individual series, whilst ξ_i^* and ζ^{*2} are the mean and the variance of the individual modified $MSB_i^*(\lambda_i)$, respectively. Finally, $\lambda_i = TB_i/T$ is the break fraction parameter.

II.2.2.2. Structural breaks in panel data

As we have mentioned above, we are interested in analyzing the possible effect of certain events, such as the Great Recession, on the relationship between health outcomes and the certain socioeconomic/environmental variables. To do so, we take into account the results of Karavias *et al.* (2022) and Ditzen *et al.* (2022), who develop methods for testing for structural breaks in data panels. We should note that these methods are based on the contributions of Bai and Perron (1998, 2003) and Qu and Perron (2007), who pioneered the field of estimation and testing under the presence of multiple structural breaks.

Following Ditzen *et al.* (2022), let us consider this model:

$$y_{it} = x_{it}'\beta + w_{it}'\delta_j + e_{it} \;\; i = 1,2, \dots, N \quad t = 1, 2, \dots, T \qquad (7)$$

With $t = T_{j-1}, \dots, T_j$, $j = 1, 2, \dots, s + 1$, with $T_0 = 0$ and $T_{s+1} = T$, where $T_j = [\lambda_j T]$ and $\lambda_0 = 0 < \lambda_1 < \cdots < \lambda_s < \lambda_{s+1} = 1$. The dependent variable is y_{it}, whilst x_{it} and w_{it} are the set of regressors of dimension $px1$ and $qx1$, respectively. The difference between them lies in the fact that the parameters included in vector β are not affected by the breaks, whilst the vector δ_j changes across the different regimes. We should note that we are assuming that the breaks are common for all N units. Finally, e_{it} is the regression error, which is defined as

$$e_{it} = f_t'\gamma_i + \varepsilon_{it} \qquad (8)$$

in order to allow for unobserved heterogeneity in the form of interactive effects, with f_t being a mx1 vector of factors and γ_i its corresponding vector of factor loadings. Both f_t

and ε_{it} may be weakly serially correlated but cannot be correlated with each other and ε_{it} cannot exhibit cross-sectional correlation, ensuring that the possible cross-section dependence in e_{it} originates in f_t.

To capture the possible presence of cross-sectional co-movement in the regressors, Ditzen *et al.* (2002) also assume that that $x_{i,t}$ and $w_{i,t}$ are generated as follows:

$$x_{i,t} = \Gamma'_{x,i} f_t + u_{x,i,t} \tag{9}$$

$$w_{i,t} = \Gamma'_{w,i} f_t + u_{w,i,t} \tag{10}$$

Where $\Gamma_{x,i}$ and $\Gamma_{w,i}$ are pxm and qxm matrices of factor loadings, respectively. Similarly, while $u_{x,i,t}$ and $u_{w,i,t}$ are $px1$ and $qx1$ vectors of idiosyncratic errors, respectively, that are independent of all the other random elements of the model. Consequently, the use of the set of regressors generates endogeneity problems. To deal with this issue, and assuming that the common factors are unknown, Ditzen *et al.* (2022) propose to estimate the following equation:

$$y_{it} = x'_{it}\beta + w'_{it}\delta_j + \bar{x}'_t a_i + \bar{w}'_t b_{i,j} + \xi_{it} \tag{11}$$

Where $\bar{x}_t = N^{-1}\sum_{i=1}^{N} x_{i,t}$ and $\bar{w}_t = N^{-1}\sum_{i=1}^{N} w_{i,t}$. Ditzen *et al.* (2022) note that this estimation method is quite similar, but not identical, to the common correlated effects one proposed by Pesaran (2006, 2021).

In order to estimate the model (11), it is first necessary to determine the number of breaks and the period where these breaks appear. To that end, we should note that Dizten *et al.* (2022) prove the consistency of the following estimator:

$$\hat{\mathcal{T}}_s = \arg\min_{\mathcal{T}_s \in \mathcal{T}_{s,\epsilon}} SSR(\mathcal{T}_s) \tag{12}$$

With $SSR(\mathcal{T}_s)$ being the sum of the squared residuals for the combination of break dates that holds

$$\mathcal{T}_{s,\epsilon} = \left\{(T_1, T_2, \dots, T_s) : T_{j+1} - T_j \geq \epsilon T, T_1 \geq \epsilon T, T_s \leq (1-\epsilon)T \right\} \tag{13}$$

Where ϵ is the trimming parameter (15% is the value commonly employed).

In order to select the values of the parameter s, Ditzen *et al.* (2022) suggest the use of several statistics. For instance, if the break points are known, we can employ the Chow-type statistic $F(\mathcal{T}_s)$ to test the null hypothesis of no breaks versus the alternative of s breaks occurred in the set of breaks at dates $\mathcal{T}_s$. If the break dates are unknown, the most habitual case, Ditzen *et al.* (2022) suggest the use of the following supremum statistic:

$$\sup F(s) = \sup_{\mathcal{T}_s \in \mathcal{T}_{s,\epsilon}} F(\mathcal{T}_s) \tag{14}$$

If we are interested in testing the no breaks null hypothesis versus the existence of s_{max} breaks, with s_{max} breaks being determined by the researcher, we can employ the extension of the WD_{max} statistic proposed by Bai and Perron (1998):

$$WD_{max}F(s_{max}) = \max_{1 \leq s \leq s_{max}} \frac{c_{\alpha,1}}{c_{\alpha,s}} \sup F(s) \tag{15}$$

With $c_{\alpha,s}$ being the critical value of sup $F(s)$ at significance level α and s breaks.

Finally, we can also use the extension of the sequential type statistics proposed by Bai and Perron (1998) to test the null hypothesis of s breaks versus the alternative of $s+1$ breaks. This statistic is defined as follows:

$$F(s+1|s) = \sup_{1 \leq j \leq s+1} \sup_{\tau \in \hat{\mathcal{T}}_{j,\varepsilon}} F(\tau|\hat{\mathcal{T}}_s) \tag{16}$$

Where $\hat{\mathcal{T}}_s$ contains estimates of the s breaks considered under the null hypothesis, τ is the additional (s+1)-th break under the alternative hypothesis and

$$\hat{\mathcal{T}}_{j,\epsilon} = \left\{\tau: \hat{\mathcal{T}}_{j-1} + \Delta\hat{\mathcal{T}}_j\epsilon \leq \tau \leq \hat{\mathcal{T}}_{j-1} - \Delta\hat{\mathcal{T}}_j\epsilon\right\} \tag{17}$$

is the set of permissible breaks in between the estimated (j − 1)-th and j-th breaks and $F(\tau|\hat{\mathcal{T}}_s)$ is the Chow-type statistic on taking the estimated break dates in $\hat{\mathcal{T}}_s$ s as given and testing for one additional break at τ.

The distributions of these statistics, and the assumptions needed to derive them, are presented in Ditzen *et al.* (2022). We should note that these distributions are obtained under the assumption that N, T goes to infinity, with T/N going towards 0. Given this, T should be large and N should be even larger. We should note that this is not our case.

Therefore, it seems appropriate to consider the results based on the Common Correlated Effects (CCE) estimations, as well as those based on the standard estimation. Moreover, the selection of the number of breaks may be also influenced by this fact. Therefore, we will also select them by analyzing the evolution of the sum of the squared residuals, as is done in the seminal papers of Bai and Perron (1998, 2003). We should recall that Karavias *et al.* (2022) and Dizten *et al.* (2022) prove that the minimization of this value is a consistent estimator of the periods when the breaks occur.

Once we have analysed the time series properties of the variables and taken into account the potential presence of instability in the parameters, we will proceed to estimate the relationship between health outcomes and the explanatory variables, using specification (7) with fixed effects and CCE estimation.

II.3. Results

This Section presents and discusses the most important results obtained.

II.3.1. Time series properties

Table 2 presents the results of the CD and CDw test for testing the null hypothesis of cross-section independence. To that end, we have first estimated a panel Augmented Dickey-Fuller (ADF) equation with a different number of lags and we have employed the Ordinary Least Squares (OLS) residuals to test the abovementioned hypothesis. The null hypothesis is rejected at the 1% significance level for both CD and CDw statistics across all variables considered. Consequently, we should conclude that the perturbations of the models exhibit a high degree of cross-section correlation, as could be expected. This outcome underscores the necessity of employing second-generation data panel unit root statistics.

The results of these statistics are reported in Table 3. The use of the CIPS* statistics provides weak evidence against the presence of a unit root in our set of variables. However, the evidence against the unit root null hypothesis is very robust when we use the statistics proposed in Bai and Carrion-i-Silvestre (2009), which allow for the presence of breaks in the trend function. Once these breaks are accounted for, the rejection of the null hypothesis of unit root becomes clear for all variables. These results highlight the importance of considering the possible presence of structural breaks in the time series when we analyze the relationship between our variables.

II.3.2. Panel data estimation

Once we have analyzed the time series properties of the variables, we can proceed to estimate their relationship. The initial results are presented in Table 4. We should note that these results are obtained by using a fixed effects estimator and, therefore, the results may be contaminated by neglecting both cross-sectional correlation and structural breaks, questions that will be analyzed subsequently. This initial estimation highlights the existence of evident gender differences in the estimation. While the elasticities of GDP and HEXP remain relatively stable when considering $PM_{2.5}$ (-0.27/-0.26 for male/female, and -0.20/-0.19 for male/female, respectively), the estimated elasticities of GDP and HEXP differ between male and female cases when considering the other environmental variables. In addition, the sum of the GDP and HEXP elasticities is quite similar for the different models considered. Furthermore, it is noted that the male GDP elasticity is slightly greater (in absolute terms) than the female elasticity across all cases examined. Consequently, this initial analysis provides new arguments indicating the existence of gender differences.

However, we should interpret these results with some caution given that possible presence of cross-sectional correlation and structural breaks. To account for this, Panel I in Table 4 incorporates the CD and CDw statistics, which test for the presence of cross-sectional dependence. We can observe that the evidence against this hypothesis is clear, as we reject the null hypothesis of cross-sectional independence at the 1% significance level for all cases considered. As such, we should consider this when calculating the statistics for testing the null hypothesis of no structural breaks.

The analysis of the presence of structural breaks is reflected in Panel II of Table 4, which presents the results of the statistic proposed by Ditzen *et al.* (2022). The case A does not correct for possible cross-sectional dependence and the case B is based on the inclusion of the cross-sectional averages of the explanatory variables, using CCE estimation. We should also note that in both cases we have admitted the existence of breaks in the fixed effect parameters, and have used a trimming parameter equal to 0.15, using the

Heteroscedasticity and Autocorrelation Consistent (HAC) estimation of the covariance of the estimators, and that we have considered that $x_{it}'\beta$ is 0 in (11).

The use of both the sequential F and the UD_{max} statistics provides robust evidence against the null hypothesis of no structural breaks when the panel is estimated by standard methods. The results are somewhat similar when we correct for the presence of cross-sectional correlation and use the CCE estimator. However, the evidence against the null hypothesis of no structural changes is limited in this case when using UD_{max}. Furthermore, we can also observe a certain degree of overestimation of the number of breaks. Therefore, we can conclude that the evidence in favor of the presence of breaks is solid, although the determination of its number is not so clear. In order to solve this puzzle, we have opted to select the number of breaks by imposing a maximum number of breaks of 2[2] and determining the periods where the break appears by taking into consideration the evolution of the sum of squared residuals in comparison to the number of parameters estimated.

Once we have selected the presence of two breaks, we can observe that the estimations of the break periods are quite similar for the male and the female case. The first break appears around the beginning of the 21st century, whilst the second one is clearly related to the Great Recession, confirming our suspicion regarding the relevance of this period in the evolution of the analyzed relationship. Finally, we should note that the conclusion does not vary much for the various measures of the environmental degradation employed.

The results obtained in the presence of breaks are reflected in Table 5, where the total sample is divided into three periods: 1900-1999, 2000-2008, and 2009-2019. Let us first examine the case of the GDP and HEXP estimated elasticities. We can appreciate that these estimated elasticities are consistently negative, indicating that increases in these variables correspond to reductions in potential years of life lost (improving the health status of the population).

The separated analysis of these two estimated elasticities is also insightful. The reduction of the GDP elasticity after GR, which is compensated with an increment of the HEXP elasticity, is particularly noticeable. Although economic growth may be lower than in previous periods, its impact on premature mortality is offset by the effect of health spending. This suggests that HEXP plays a crucial role in reducing premature mortality, even in times of only moderate economic growth.

We can also see that the estimated elasticity of GDP is higher for the male case than for the female one, indicating gender disparities, which are particularly noticeable since the Great Recession. To see this, we should note that the male/female elasticity of GDP stands at -0.21/-0.14, when using $PM_{2.5}$, whilst this is -0.25/-0.14, when using CO_2. By contrast, these gender differences are less pronounced when considering HEXP.

The analysis of environmental degradation elasticities appears to be particularly relevant. We can see that environmental degradation has a negative impact on health, with the impact diminishing over time when considering $PM_{2.5,}$ but it increases for other environmental degradation variables, especially for CO_2.

Our results reflect that the effect of environment on health is clearly not gender-neutral, with this being true independently of the environmental degradation indicator. More precisely, we can appreciate that the estimation of male environmental elasticity is clearly higher than female, even doubling in some periods. It is also important to note that following the Great Recession, gender differences have increased.

II.4. Discussion

Two main points emerge from the analysis of the results of the precedent section. On the one hand, we can see that the relationship between health, economics and environment is not stable across time. On the other hand, we have also observed that this relationship is not gender neutral. To better appreciate the implications of the results, let us now consider the analysis of the different elasticities.

Let us first consider the GDP elasticity. We can see that GDP has an overall positive effect on the health status of the population, as deduced from Mackenbach *et al.* (2019), Murthy *et al.* (2021) and Tavares (2022), amongst many others. These authors suggest that an increase in GDP can lead to positive effects on health due to factors such as greater access to healthcare services, the acquisition of higher-quality goods, jobs which are less detrimental to health, and a more educated population. Our results also show that some significant gender differences in how economic conditions affect health exist. For instance, the estimated male GDP elasticity is around 1.6 times the estimated female one after the GR.

If we now consider the case of the HEXP, we also ascertain that higher health expenditure means longer life, confirming the relationship also found in the literature. We can cite Tavares (2022) and Varbanova and Beutels (2020) in this regard. This result is easily understood if we consider that this is clearly linked to improving accessibility to medical services, raising the quality of care, implementing prevention programs, developing health infrastructure and promoting equity in access, as well as reducing socio-economic disparities in health care. Nevertheless, it is important to bear in mind that the impact of health expenditure depends not only on the number of financial resources, but also on the efficiency of the management of those resources and the implementation of effective health policies (Ledesma-Cuenca *et al*., 2022). In this regard, we note that HEXP elasticities show a markedly increasing pattern of behavior (in absolute terms), whilst this variable has shown a clear reduction in its growth rate, as was seen in the descriptive analysis. Therefore, we should conclude that there is an increase in the efficiency of the health expenditure.

The HEXP elasticities also show notable disparities by gender, with this being in line with some previous results, such as those of Ferreira *et al.* (2018) and Amendola *et al.* (2020). These authors provide a possible explanation for this: when cuts are implemented in the health care system, women experience the adverse effects to a greater extent. This may be because, as Owens (2008) highlights, women tend to use more health care services, face a higher incidence of acute illness, require reproductive care services, and often need long-term care due to their longer life expectancy. Therefore, health expenditure reduction measures may have a more immediate and pronounced impact on females.

Finally, we should consider the effects of the variables that measure the impact of environmental degradation on health. The overall result is what was expected, and we can see a negative relationship between environmental degradation and health. Even more importantly, we can find marked gender differences, with the estimation of the male elasticity being greater than the female one. This result remains qualitatively valid for the different environmental indicators considered and is in line with the recent studies of Shin *et al.* (2022) or Liao *et al.* (2023). These authors associate these gender disparities to biological, social and lifestyle factors. In particular, we should note the fact that different daily activities and lifestyles affect exposure, with variations in mobility and workplaces. Gender-specific immune responses may influence how the body defends itself against adverse effects. Socio-economic factors, such as the wage gap and caregiver roles, also contribute, along with sensitivity to chemicals. It is important to recognize the relevance of these variables, bearing in mind that the association between gender and environmental degradation is a developing area of study that it is also influenced by factors such as age, geographic location and individual health status, as Aliyu and Ismail (2016) and Clougherty (2010) also point out.

Our findings highlight the significant gender differences identified in the effect of environmental degradation on health, as well as how economic changes influence this relationship, underscoring the need for tailored interventions to reduce disparities in health outcomes.

II.5. Conclusions

The paper aims to analyse the relationship between health outcomes, economics factors, and environmental degradation, with special emphasis on potential gender differences, under the possible presence of structural breaks.

Our results offer evidence on the existence of two structural breaks in the relationship between the previously mentioned variables: the first one related to the change of the century and the second one clearly associated to the Great Recession. Assuming the presence of these breaks, we can observe that with higher GDP and HEXP, the population's health improves, leading to a reduction in premature mortality rates. By contrast, environmental degradation affects negatively to health. This effect is particularly clear when $PM_{2.5}$ is used, due to its ability to penetrate deep into the lungs, reinforcing the idea that this is crucial indicator to measure effects of environment on health. However, we should note that similar results are obtained when using different measures of environmental degradation.

The most important finding is the presence of marked gender differences in the effect of variables on health, which are particularly noticeable for environmental degradation indicators. Estimated female elasticities are mostly lower that male ones, indicating varying levels of susceptibility and exposure to environmental risks. Furthermore, these differences in estimated elasticities increase after the Great Recession.

The analysis emphasizes the importance of incorporating gender considerations in the design of public health policies and programs that consider these differences in access to healthcare, exposure to environmental risks, and responses to economic crises. Additionally, ongoing research and monitoring of these disparities are essential to ensure that future interventions and policies are effective and equitable for all population groups. Policy interventions must recognize these complexities to effectively tackle environmental and health challenges, with gender-responsive approaches playing a crucial role in promoting equitable access to healthcare and the safeguarding of public health.

II.6. Notes

[1] See Zhang *et al.* (2008), Shah *et al.* (2011), Giaccherini *et al.* (2021), Afoakwah *et al.* (2020) and Owusu and Sarkodie (2020) in this regard.

[2] The analysis of the values of the SSR also justify this decision. For instance, let us consider the case of the variable YPLLm (Case B). SSR is 0.27, 0.17 and 0.11 for 1, 2 and 3 breaks, respectively.

II.7. Figures and tables

Table 1: Descriptive analysis

	PYLLm			PYLLf			GDP			HEXP			CO_2			$PM_{2.5}$		
	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19
Australia	-2.0	-2.7	-0.8	-1.9	-2.4	-1.1	3.8	4.6	2.4	5.2	6.0	4.2	-0.1	1.0	-1.8	-0.4	-0.6	-0.1
Austria	-2.6	-2.9	-2.6	-2.1	-2.6	-1.8	3.8	4.3	3.6	4.7	5.7	3.2	-0.1	0.6	-0.6	-1.9	-1.6	-2.5
Belgium	-2.2	-2.0	-2.5	-1.7	-1.8	-1.7	3.8	4.0	3.7	5.0	5.7	3.7	-1.0	-0.5	-1.3	-1.7	-1.4	-2.4
Canada	-1.9	-2.4	-0.8	-1.4	-1.6	-1.1	3.1	3.9	2.4	3.9	4.7	2.8	0.1	0.5	-0.1	-1.2	-1.1	-1.4
Czech Republic	-2.8	-3.1	-2.3	-2.5	-2.9	-1.8	4.3	4.5	4.5	6.8	7.6	4.8	-1.6	-1.3	-1.6	-1.5	-1.3	-1.9
Denmark	-2.6	-2.4	-2.7	-2.5	-2.4	-2.8	4.1	4.6	3.8	4.6	5.5	2.9	-2.3	-0.6	-5.2	-1.9	-1.5	-2.7
Finland	-2.7	-2.5	-3.1	-2.0	-2.1	-2.1	3.6	4.5	2.9	4.4	5.4	2.9	-1.4	-0.1	-3.1	-1.6	-1.1	-2.3
France	-2.4	-2.3	-2.9	-1.4	-1.7	-0.9	3.6	3.9	3.5	4.5	5.4	2.9	-1.1	-0.5	-1.7	-1.7	-1.2	-2.5
Germany	-2.3	-2.8	-1.4	-1.9	-2.5	-1.0	3.7	3.9	4.0	4.6	4.7	4.4	-1.4	-1.2	-1.3	-1.9	-1.5	-2.6
Greece	-1.2	-1.3	-1.3	-1.7	-2.5	-0.6	2.9	4.8	0.0	3.9	7.1	-1.5	-1.0	1.1	-4.1	-1.2	-0.4	-2.6
Hungary	-2.5	-2.1	-3.1	-2.3	-2.3	-2.3	5.1	5.5	5.0	4.6	5.6	3.4	-1.1	-1.2	-0.1	-1.5	-1.3	-1.8
Iceland	-2.5	-3.4	-1.8	-2.3	-3.0	-0.4	3.4	3.9	3.4	3.5	4.7	2.2	-1.8	-0.6	-3.7	-0.8	-0.5	-1.4
Ireland	-2.8	-2.5	-3.9	-2.4	-2.4	-2.5	6.6	6.7	7.8	6.7	9.2	2.5	-0.7	0.8	-2.1	-1.7	-1.3	-2.3
Italy	-2.7	-3.0	-2.3	-2.1	-2.5	-1.7	3.0	3.6	2.6	3.6	4.7	2.0	-1.0	0.3	-2.3	-1.8	-1.4	-2.3
Japan	-1.9	-1.6	-2.5	-1.7	-1.7	-1.7	2.6	3.1	2.4	5.1	5.4	4.5	-0.1	0.1	-0.1	0.1	-0.6	1.3
Korea	-3.7	-3.7	-3.8	-3.4	-3.5	-3.5	5.8	7.4	3.8	8.0	8.5	6.9	2.5	3.4	1.0	0.3	-0.4	1.6
Netherlands	-2.4	-2.7	-1.9	-1.6	-1.5	-1.6	4.0	5.0	2.9	4.9	6.5	2.5	-0.6	0.1	-1.4	-1.7	-1.4	-2.3
Norway	-3.1	-2.8	-3.7	-2.2	-2.1	-2.7	4.5	6.9	1.9	5.5	7.0	3.3	-0.1	0.6	-1.4	-2.0	-2.0	-1.8
Poland	-2.1	-1.9	-2.2	-2.2	-2.3	-2.0	6.0	6.2	5.8	7.1	8.1	5.5	-0.6	-0.7	0.0	-1.3	-1.1	-1.6
Portugal	-2.5	-2.8	-2.2	-2.6	-3.1	-2.0	4.0	4.7	3.2	5.8	7.8	2.5	0.2	1.5	-2.0	-1.2	-0.7	-2.0
Spain	-2.7	-2.7	-2.6	-2.3	-2.5	-1.8	4.0	5.1	2.7	5.2	6.8	2.5	-0.3	1.4	-2.0	-1.3	-0.9	-1.8
Sweden	-2.3	-2.6	-1.7	-1.9	-2.0	-1.6	3.5	4.1	3.1	4.5	4.7	4.6	-2.1	-1.2	-3.0	-1.9	-1.6	-2.4
Switzerland	-3.1	-3.3	-3.0	-2.3	-2.4	-2.2	3.3	3.6	3.0	4.2	4.7	3.2	-1.3	-0.5	-2.5	-2.0	-1.7	-2.5
United Kingdom	-2.0	-2.1	-1.5	-1.7	-1.9	-1.2	3.7	4.4	3.3	6.1	8.2	2.8	-2.2	-0.9	-3.6	-1.9	-1.7	-2.1
United States	-1.1	-1.7	0.1	-0.8	-1.1	-0.2	3.5	4.0	3.2	4.9	5.8	3.6	-1.0	-0.3	-1.4	-1.9	-1.7	-2.3

The table presents the growth of the variables (in %) for the periods 1990-2019, 1990-2008 and 2008-2019.

Table 2. Testing for cross-sectional independence

	CD	CDw
PYLLm	92.26 ***	-10.30***
PYLLf	92.37 ***	-10.21***
GDP	93.45 ***	-10.29***
HEXP	92.84 ***	-10.27 ***
$PM_{2.5}$	69.10 ***	-3.92 ***
CO_2	46.85 ***	-2.99 ***
N_2O	72.49 ***	-9.27 ***
CH_4	72.61 ***	-10.07 ***
VOCs	85.71***	-0.56
CO	73.54***	-3.00***
NO	71.03***	-1.07

This table presents the values of the CD statistic proposed by Pesaran (2015, 2021) and the one of Juodis and Reese (2022) for testing the null hypothesis of cross-sectional independence. These statistics have been applied to the logs of the variables. *** means rejection of the null hypothesis at the 1% significance level.

Table 3. Panel data unit root tests

	CIPS*				Bai and Carrion-i-Silvestre		
	P=0	P=1	P=2	P=3	Z	P_m	P
YPLLm	-4.10 ***	-1.84 **	-0.78	-1.78 **	8.90	10.47 ***	154.75 ***
YPLLf	-6.75 ***	-1.23	0.70	0.47	14.28	194.01***	1990.10 ***
GDPpc	3.98	3.37	3.98	3.64	19.15	4.39 ***	93.98 ***
HEXPpc	2.26	0.73	1.25	1.90	13.41	30.72 ***	357.18 ***
$PM_{2.5}$	1.88	4.39	6.97	2.88	26.37	30.27 ***	352.78 ***
CO_2	-4.04 ***	-3.13 ***	-1.02	-1.36 *	11.04	59.58 ***	645.80 ***
N_2O	-1.50 *	-1.11	-0.86	-0.02	6.38	197.99 ***	2,029.95***
CH_4	1.26	-0.44	0.63	-1.12	11.32	137.32 ***	1,423.16***
VOCs	-2.32 **	-1.67*	0.35	0.75	9.06	126.54 ***	1287.86***
CO	-1.72 *	0.49	1.60	2.85	5.87	27.32 ***	315.68 ***
NO	-2.43 ***	-1.75 **	-0.42	0.84	4.21	31.76 ***	359.20 ***

This table provides the CIPS* statistics (for p lags, with p=0, 1, …,3) proposed by Pesaran (2007) and the simplified Z, Pm, and P statistics proposed by Bai and Carrión-i-Silvestre (2009). These statistics aim to test the null hypothesis of a unit root in panel data. Critical values for rejecting the unit root hypothesis at the 1% and 5% levels are 2.326 and 1.645, respectively, for both Z and Pm. For the P test, chi-square critical values are determined using 2N degrees of freedom corresponding to the relevant significance levels. Significance levels are denoted by ***, **, and *, indicating rejection of the null hypothesis at the 1%, 5%, and 10% significance levels, respectively.

Table 4. Estimation for the total sample

	ENV= $PM_{2.5}$		ENV= CO_2		ENV= N_2O		ENV= CH_4		ENV= VOCs		ENV=CO		ENV=NO	
Elasticity	male	female	male	female	male	female	male	female	male	female	male	female	male	female
GDP	-0.27^{***}	-0.26^{***}	-0.33^{***}	-0.25^{***}	-0.40^{***}	-0.29^{***}	-0.37^{***}	-0.27^{***}	-0.41^{***}	-0.31^{***}	-0.42^{***}	-0.31^{***}	-0.40^{***}	-0.30^{***}
	(-2.51)	(-2.68)	(-3.80)	(-3.33)	(-4.91)	(-3.64)	(-4.13)	(-3.46)	(-5.20)	(-4.30)	(-4.42)	(-3.70)	(-5.12)	(-4.29)
HEXP	-0.20^{***}	-0.19^{***}	-0.20^{***}	-0.19^{***}	-0.10	-0.16^{**}	-0.15^{**}	-0.19^{***}	0.02	-0.06	-0.05	-0.11^{**}	-0.05	-0.10^{***}
	(-2.70)	(-3.00)	(-2.81)	(-3.12)	(-1.55)	(-2.28)	(-2.12)	(-2.89)	(0.33)	(-1.09)	(-0.67)	(-2.21)	(-0.98)	(-2.00)
ENV	0.22	0.03	0.14^{*}	0.08	0.18^{**}	0.08	0.11	0.00	0.26^{***}	0.14^{***}	0.12^{**}	0.05	0.18^{***}	0.10^{**}
	(1.34)	(0.24)	(1.86)	(1.08)	(2.76)	(1.50)	(1.39)	(0.01)	(6.39)	(4.72)	(2.08)	(0.93)	(2.92)	(2.23)
Panel I. Testing for cross-sectional dependence														
CD	6.09^{***}	2.65^{***}	3.96^{***}	0.99	6.43^{***}	2.16^{**}	6.75^{***}	3.16^{***}	3.72^{***}	1.37	5.48^{***}	2.38^{**}	3.33^{***}	1.84^{*}
CDw	-1.02	-2.59^{***}	-1.75^{*}	10.05^{***}	-0.08	-1.21	-0.50	4.84^{***}	-1.25	-1.67^{*}	0.27	-1.40	1.33	-1.38
Panel II. Testing for the presence of structural breaks														
Case A. Standard Estimation														
Fseq	1997	1998	2001	1995	1995	1998	2003	1996	1997	1995	2002	1996	2000	1999
	2002	2010	2012	1999	2002	2010		2000	2011	1999	2011	2003	2012	2012
	2006			2003	2006			2005		2006		2008		
	2010			2008	2010			2010		2012		2012		
	2014			2012	2014			2015						
UD_{max}	10.83^{***}	5.93^{***}	7.94^{***}	6.97^{***}	7.84^{***}	6.07^{**}	5.84^{**}	4.12	7.55^{***}	4.62^{*}	2.94	6.07^{**}	10.18^{***}	9.91^{***}
SSR	1997	1998	2001	1998	1997	1998	2000	1998	1997	1998	2002	1998	2000	1999
	2010	2010	2012	2010	2011	2010	2011	2009	2011	2009	2011	2009	2012	2012
Case B. CCE estimation														
Fseq	1994	1995	1995	-	-	1995	-	1998	-	-	-	1996	-	-
	1999	2006	1999			2009		2009				2003		
	2008	2013	2004									2008		
			2009									2012		
UD_{max}	2.29	2.25	2.13	3.77	5.32^{**}	5.44^{**}	4.16^{*}	3.48	1.55	2.97	1.54	2.68	2.51	2.59
SSR	1999	2001	1999	1996	1999	1995	1997	1998	1997	1998	1999	1998	1999	1998
	2008	2012	2009	2009	2008	2009	2008	2009	2007	2012	2009	2012	2009	2012

This table presents the estimation of model (7), assuming that $x_{it}'\beta = 0$ and using fixed effects. Panel I present the CD and CDw statistics, developed in Pesaran (2015) and Juodis and Reese (2022), respectively, for testing for cross-sectional dependence. Panel II presents the results of applying the methodology developed in Ditzen *et al.* (2022) for testing for multiple structural breaks when we consider a trimming parameter of 0.15 and allow for changes in the fixed effects. The row Fseq presents the estimation of the breaks obtained by using the sequential F statistics. The row UDmax reflects the values of the statistic for testing the null hypothesis of no structural breaks vs a maximum number of breaks of 5. The row SSR presents the estimations of the periods when the breaks occur via minimization of the sum of the squared residuals once we have imposed a maximum number of breaks of 2. Case A does not consider the presence of cross-sectional dependence, whilst Case B corrects this issue by using the CCE estimation, including the cross-sectional averages of the explanatory variables and a common factor based on the variable GDP. ***, ** and * means rejections at the 1%, 5% and 10% significance level, respectively

Table 5. Estimations under the presence of structural breaks

	ENV= $PM_{2.5}$		ENV= CO_2		ENV= N_2O		ENV= CH_4		ENV= VOCs		ENV=CO		ENV=NO	
	male	female	male	female	male	female	male	female	male	female	male	female	male	female
Panel I. 1990-1999														
GDP	-0.16	-0.13	-0.38***	-0.25***	-0.36***	-0.24**	-0.31**	-0.22**	-0.35**	-0.22**	-0.28*	-0.17	-0.43***	-0.27**
	(-1.44)	(-1.41)	(-2.95)	(-2.63)	(-2.85)	(-2.42)	(-2.65)	(-2.67)	(-2.52)	(-2.15)	(-1.87)	(-1.56)	(-3.28)	(-2.56)
HEXP	-0.10	-0.17***	-0.12	-0.19***	-0.10	-0.19***	-0.12*	-0.17***	-0.03	-0.13*	-0.06	-0.15***	-0.02	-0.13*
	(-1.59)	(-3.10)	(-1.55)	(-3.19)	(-1.18)	(-2.98)	(-1.77)	(-3.31)	(-0.36)	(-1.97)	(-0.66)	(-2.18)	(-0.21)	(-1.80)
ENV	0.87***	0.50***	0.14	0.07	0.12*	0.04	0.21*	0.18*	0.21***	0.14***	0.20***	0.13***	0.18***	0.12**
	(4.91)	(2.92)	(1.67)	(1.08)	(1.91)	(0.94)	(1.80)	(1.87)	(3.63)	(2.94)	(3.99)	(3.68)	(3.19)	(2.66)
Testing for cross-sectional dependence														
CD	1.49	0.84	1.72*	0.58	1.67*	0.47	1.10	0.62	1.45	1.93*	2.10**	1.31	2.50**	1.77*
CDw	0.29	-0.53	-0.45	-0.51	1.04	1.50	-0.13	-1.15	0.16	2.07**	-1.02	5.55***	1.34	-0.81
Panel II. 2000-2008														
GDP	-0.29***	-0.33***	-0.28***	-0.33***	-0.30***	-0.34***	-0.29***	-0.33***	-0.22**	-0.31***	-0.34***	-0.37***	-0.32***	-0.35***
	(-3.49)	(-4.23)	(-3.87)	(-4.82)	(-4.94)	(-4.94)	(-4.25)	(-4.63)	(-2.51)	(-4.17)	(-5.32)	(-5.02)	(-5.26)	(-5.78)
HEXP	-0.12	-0.07	-0.21***	-0.12*	-0.15**	-0.10	-0.14	-0.10	-0.11	-0.06	-0.09	-0.07	-0.09	-0.04
	(-1.12)	(-0.88)	(-2.92)	(-1.96)	(-2.35)	(-1.45)	(-1.67)	(-1.23)	(-1.22)	(-0.82)	(-1.26)	(-1.24)	(-1.54)	(-0.81)
ENV	0.47*	0.24	0.12	0.05	0.11**	0.06	0.20	0.09	0.21***	0.10	0.07	0.01	0.18*	0.12*
	(1.81)	(1.17)	(1.08)	(0.60)	(2.17)	(1.53)	(1.67)	(1.23)	(2.86)	(1.55)	(0.97)	(0.19)	(2.01)	(1.74)
Testing for cross-sectional dependence														
CD	-1.72*	-0.46	0.18	0.63	-0.35	0.66	-0.79	0.40	-0.70	0.40	-0.10	0.28	2.37**	2.56***
CDw	-1.29	0.53	-0.59	-0.60	-0.77	-1.31	1.56	-0.17	-1.60	3.54***	-0.58	-0.48	-1.75*	0.85
Panel III. 2009-2019														
GDP	-0.21**	-0.14***	-0.25***	-0.14***	-0.31***	-0.19***	-0.28***	-0.18***	-0.28***	-0.19***	-0.24***	-0.14***	-0.25**	-0.17**
	(-2.24)	(-2.46)	(-2.95)	(-2.25)	(-3.75)	(-3.28)	(-3.09)	(-2.85)	(-3.11)	(-3.39)	(-2.42)	(-2.23)	(-2.39)	(-2.60)
HEXP	-0.25**	-0.24***	-0.24**	-0.23***	-0.25**	-0.24***	-0.17	-0.18**	-0.07	-0.11	-0.17	-0.18***	-0.11	-0.14**
	(-2.11)	(-2.84)	(-2.05)	(-2.57)	(-2.30)	(-2.93)	(-1.60)	(-2.22)	(-0.69)	(-1.58)	(-1.57)	(-2.31)	(-1.24)	(-2.15)
ENV	0.19*	0.09	0.17**	0.17***	0.01	0.01	0.28*	0.21**	0.34***	0.21***	0.14*	0.11*	0.19*	0.12*
	(1.82)	(1.12)	(2.04)	(2.83)	(-0.12)	(0.24)	(1.99)	(2.32)	(5.67)	(5.44)	(1.93)	(1.96)	(2.00)	(1.76)
Testing for cross-sectional dependence														
CD	7.13***	4.24***	7.90***	4.90***	8.47***	5.50***	8.38***	5.28***	5.08***	3.60***	7.64***	4.96***	9.61***	6.25***
CDw	-0.90	-0.46	-0.10	-0.39	-1.10	-2.06**	-0.28	-0.90	6.13***	-0.89	-0.65	-1.87*	-0.99	-0.81

This table presents the estimation of model (7), assuming that $x_{it}'\beta = 0$ and using fixed effects. The estimated breaks have been selected by using the results of Table 4. The values in parenthesis mean the robust t-ratios. CD and CDw are the Pesaran (2015, 2021) and the Juodis and Reese (2022) statistics, respectively. These statistics test for cross-sectional dependence. ***, ** and * means rejections at the 1%, 5% and 10% significance level, respectively.

Chapter III: Health Determinants in Spain: Gender-based differences

III.1. Introduction

Spain is among the OECD countries with the lowest premature mortality, ranking fifth for female and eleventh for male in 2021. This ranking reflects that, although Spain remains one of the best-performing countries in terms of premature mortality, there is a notable gender gap.

The determinants behind these health inequalities are complex and multidimensional, showing that these disparities are not explained solely by natural causes, but are rooted in structures, institutions and policies that shape the living conditions, work, education and social environment of the population (Whitehead and Dahlgren, 2006, 2007; Dahlgren and Whitehead, 2021). Analysing these non-medical aspects, which are often excluded from conventional health systems, reveals how socially controllable elements can have profound consequences for collective health (Smith *et al.*, 1990; Acheson, 1998; Marmot *et al.*, 2013; Álvarez *et al.*, 2022).

The existent literature refers to these factors as social determinants of health, commonly grouped under the model known as the 'Rainbow Model', proposed by Dahlgren and Whitehead in 1991. This approach emphasizes that health does not depend exclusively on individual behaviour, but is influenced by a combination of social, structural and environmental factors (Dyar *et al.*, 2022). Subsequently, in 2003, the World Health Organization (WHO) expanded this approach to include a broader range of determinants and highlighted how policies and social structures can perpetuate health inequalities, calling them "Social Determinants of Health" (SDH).

A substantial body of literature examines the relationship between social determinants of health (SDOH) and various health outcomes. For instance, previous studies have demonstrated a strong correlation between socioeconomic deprivation and the prevalence and incidence of certain chronic diseases, while low educational attainment is associated with higher rates of premature mortality (Ruiz *et al.*, 2024). Additionally, this research emphasizes the significant role of the environment within the context of SDOH. In particular, environmental degradation, especially concerning the decline in air quality, has been found to have a substantial impact on respiratory health in Spain. In this regard, De Sario *et al.* (2013) indicate that poor air quality, both indoors and outdoors, is associated with an increase in respiratory problems across Europe.

On the other hand, health-related behaviour is a fundamental component of the social determinants of health (SDOH). This factor encompasses individual behaviours such as smoking, diet, physical activity, and alcohol consumption, all of which significantly influence health outcomes. Previous research has found that the rise in tobacco use among young women has led to an alarming increase in smoking-related premature mortality (Payne, 2001). Furthermore, studies like that of Busutil *et al.* (2017) highlight the negative impact of overweight on quality of life. Additionally, Dowler (2001) emphasizes that maintaining a balanced diet not only enhances physical health but also plays a crucial role in disease prevention, thereby contributing to the overall well-being of individuals.

Cultural factors, which encompass the norms and values influencing health behaviour, are essential for understanding the health of populations. Among these factors, structural sexism emerges as a significant issue. According to Homan (2019), structural sexism is defined as the systematic inequality in power and resources based on gender. Cumulative exposure to this type of sexism has been shown to correlate with an increased likelihood of experiencing long-term depressive symptoms and mental health issues. Power differentials based on gender affect both access to healthcare systems and the experiences individuals have within these systems. Furthermore, these disparities influence factors that impact health and well-being beyond the healthcare environment, as indicated by Raj *et al.* (2024) and Beccia *et al.* (2024).

Despite advancements in research on the social determinants of health (SDOH), the role of gender as a structural determinant remains a relatively underexplored area. When disaggregating data by gender, the literature does not reveal a clear pattern indicating how social determinants differentially affect males and females (Dahlin & Härkönen, 2013). The lack of consistent and robust data hampers the formulation of effective policies and the evaluation of their impact (Embrett, 2014).

Therefore, it is crucial to consider the multiple dimensions of gender inequality when investigating social determinants of health and their influence on the well-being of diverse populations, as the relationship between SDOH and population health may differ by gender (Braveman *et al.*, 2011; Spiteri and Von Brockdorff, 2019).

In this context, this research aims to address the existing gap in studies on the social determinants of health (SDH) concerning gender. To achieve this, an integrative approach is proposed, combining both medical and non-medical factors that impact population health. This approach encompasses a wide range of indicators that transcend traditional studies, allowing for a more detailed analysis of health differences between males and females.

To conduct this analysis, premature mortality is proposed as a key variable, as it provides a more comprehensive picture of the factors influencing health, rather than merely focusing on disease prevalence. Furthermore, by concentrating on deaths that could have been prevented, this approach facilitates a more accurate assessment of public health.

In contrast to previous literature, which often focuses on cross-sectional and specific studies, mainly based on health surveys (Álvarez-Gálvez *et al.*, 2023), we propose to follow a long-term perspective using time series techniques. This methodological difference allows for a deeper and more relevant analysis of health determinants, providing a completer and more contextualised picture. It allows us to analyse the evolution over several periods of the factors that produce gender health disparities. To implement this strategy, we will identify latent factors that reflect general fluctuations in the economic and socioeconomic conditions of the Spanish population, as well as introduce a new factor extraction approach by estimating common latent factors using Partial Least Squares (PLS), following Fuentes *et al.* (2015), Bennedsen *et al.* (2021) and De Juan *et al.* (2023). This different lens allows us to align the factors obtained with premature mortality through the extraction process, offering additional explanatory power for understanding premature mortality by gender.

In this context, this paper aims to analyse the economic and social determinants of premature mortality in Spain, measured by PYLL, approaching it from a gender perspective. Applying the methodology previously mentioned, through this analysis, we seek to see whether the factors are common to both genders and whether the impact of these factors is differentiated between males and females or not.

The rest of the paper is organised as follows. Section 2 describes the data used. Section 3 presents the methodology. Section 4 includes the empirical results, while Section 5 outlines the discussion. Section 6 presents the main conclusions.

III.2. Data and methods

III.2.1. Data

Our target variable is Potential Years of Life Lost (PYLL in advance). This indicator refers to the loss of life in economically productive and potentially avoidable years, since it focuses on individuals who die before the age of 70. In Spain, PYLL specifically measures the years lost due to premature deaths per 100,000 populations, and it is possible to disaggregate it by gender. This indicator is derived from the OECD database, for the period 1990-2021. The definition is given in Appendix I.

In order to describe the statistical properties of this health indicator, Table 1 shows some descriptive statistics of the original PYLL variable and its growth rates. We observe that there is no evidence against the normality of the original series according to the Jarque-Bera test (JB) (Bera and Jarque 1980, 1981), and that there is evidence against the stationarity of the series according to the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979). Therefore, as PYLL male/female is not stationary we have constructed its growth rates by taking first differences from the logarithm of the original series.

In this line, when analysing the growth rates of PYLL from 1991 to 2021, we find evidence against the normality of the series according to the JB test. Kurtosis, which is around 6.7 for both genders, indicates that the distribution of the data has heavier tails and a higher peak than a normal distribution, suggesting a leptokurtic distribution. In addition, a skewness value (1.039/1.368 for male/female) suggests a moderate skew to the right, indicating a positive asymmetric distribution. However, when removing the effect of the COVID-19 pandemic and considering growth rates until 2019, the JB test no longer shows evidence against the normality of the series. The ADF test indicates that there is no evidence against stationarity of the series, suggesting that the transformed series is stationary.

Figure 1 plots the growth rates of PYLL, for both genders. It highlights a drop around 1997, indicating an improvement in population health. This is in line with the growth of the Spanish health system between 1997 and 2008, driven by economic expansion, which allowed investment in health infrastructure and services. Moreover, during this period health decentralization was completed, transferring competences to the autonomous communities, and the National Health System Cohesion and Quality Law was passed in 2003, which sought to guarantee equity and quality in health care (Bernal-Delgado *et al.*, 2018).

The Figure 1 also reveals an increase in premature mortality that coincides with the latter part of the Great Recession. This rise corresponds with the healthcare cuts that began in Spain around 2011, reflecting the impact of austerity measures on health outcomes. Finally, there is a dramatic increase in premature deaths in 2020, clearly related to COVID-19 pandemic.

In order to determine which factors are behind the evolution of premature mortality in Spain, we relate this series to different sets of economic, socio-economic, social and environmental indicators. The data sources for building the comprehensive dataset are the Spanish Ministry of Finance and Public Administration, the Spanish National Institute of Statistics, the World Data Bank, the Human Development Reports and the OECD database. We have selected 178 indicators with annual frequency, forming a balanced dataset covering 1990 to 2021. As we try to explain the health of the Spanish population, in our macroeconomic database we include business cycle, labour market, demographic, health system and welfare, and environmental variables. Other health indicators, such as life expectancy or premature mortality, have not been included to avoid possible endogeneity problems. Since these indicators are similar variables, it is not appropriate to use one of them to explain a variable of which it is a component.

In this line, the variables in the macroeconomic database have been standardised to ensure comparability between them, to avoid biases due to differences in scales of magnitude, and to facilitate the interpretation of the results. For this purpose, the necessary transformations were performed to achieve stationarity. Following De Juan *et al.* (2023), the primary transformation applied is the calculation of growth rates using logarithms and then taking the first differences. In cases where the variables had negative values in their levels or involved growth rates, the logarithmic transformation was not applied, and only the first differences were taken. Information about the selected macroeconomic indicators for this study, including details about the database they belong to, and the transformations applied in each case, is provided in Appendix III.

Once these descriptive statistics have been established, we will employ dynamic common factors techniques to explore the determinants of health in Spain. For this analysis, we will use the previously mentioned macroeconomic indicators. The following section presents the methodology that we will purpose to that end.

III.2.2. Methodology

We propose to use a structured augmented dynamic factor model (SADFM), following the work of Bennedsen *et al.* (2021) and De Juan *et al.* (2023), to achieve our objective. They propose an augmented regression for y_t, where y_t is the growth rate of potential years of life lost of male/female in Spain, in our case. To that, let us know consider the following model:

$$y_t = \alpha + \sum_{j=1}^{k} \beta_j x_t^{(i_j)} + \beta_f' F_t + \gamma' z_t + \varepsilon_t^{(y)} \qquad (1)$$

Where $x_t^{(i_j)}$, with $j = 1, \dots, k$ and $i_j = \{1, 2, \dots, N\}$, are the pre-selected individual economic variables from X_t, and β_j is the regression coefficient for the $i_j th$. F_t is an r × 1 vector of economic factors or principal components, β_f is the r × 1 corresponding loading coefficient vector, z_t is a vector of exogenous variables not contained in X, such as dummy variables, $\gamma\,'$ is the corresponding vector of regression coefficients, and $\varepsilon_t^{(y)}$ is the disturbance term. It is assumed that the error term is an independent white noise with variance σ_y^2.

Following Stock and Watson (2002, 2016) and Giannone *et al.* (2008) model (1) can be considered as a standard regression model, to which latent dynamic factors in F_t are added, as indicated by Bennedsen *et al.* (2021). Following De Juan *et al.* (2023), model (1) can be denoted as a structural model, as opposed to a predictive one, since all regressors are temporally aligned with the dependent variable. If the coefficients associated with the common factors turn out to be zero, a more structural interpretation would be obtained between the potential years of life lost and the chosen macroeconomic indicators. In this line, the following section will proceed with the extraction of the common factors and will describe the methodology used to carry out this process.

It should again be noted that we have excluded from our macroeconomic database any variables that might have given rise to bidirectionality problems in the estimation of equation (1), and we will check whether there is any evidence of serial correlation in the residuals after estimation of the model and make the necessary modifications if detected.

Against this background, we consider three types of models. First, a pure structural model without common factors (with the restriction $\beta_f = 0_{rx1}$ in our model equation (1), being 0_{rx1} a column vector of dimension rx1) denoted by REG. Secondly, a structured augmented dynamic factor model restricted to the common factors (with the restriction $\beta_j = 0$ with $j = 1, \dots, k$ in equation (1)) denoted by R-FM. And thirdly, a full structured augmented dynamic factor model without restrictions, denoted by U-REGFM.

1.1. Dynamic factor model

Given that we have a large number of macroeconomic time series for Spain (N=178), and that our number of observations is relatively small (T=31), the formulation of a statistical model with all the individual time series present in X is not feasible. Therefore, it seems appropriate to consider a dynamic factor model in our analysis, in order to extract the common factors from our macroeconomic indicator base.

Along these lines, the basis of the SADFM is a standard dynamic factor model (DFM). The premise of these models is that the common dynamics of a large number of time series variables stem from a relatively small number of unobserved (or latent) factors, which, in turn, evolve over time (see Doz *et al.* (2012), Jungbacker and Koopman (2015), and Stock and Watson (2016), in this regard).

The DFM expresses an $N \times 1$ vector of observed time series variables X_t generated by a small set r of common unobserved or latent factors F_t such that $r <<< N$, and of an idiosyncratic component with zero mean characteristic of each time series.

The specification of the DFM is as follows:

$$X_t = \Lambda \mathrm{F}_t + \varepsilon_t^X \tag{2}$$

Where F_t is zero mean vector of time series common factors with dimension $rx1$, ε_t^X is the idiosyncratic component with dimension $Nx1$, and Λ is a factor loading matrix $\Lambda = (\lambda_{ij})$ with $i = 1, \dots, N$ and $j = 1, \dots, r$ which has Nxr dimension, that relates the common factors to the observed variables. We assume that all variables contained in X_t are transformed into stationary time series with zero mean and ε_t^X is weakly cross and serially correlated, with a full rank variance NxN matrix $var(\varepsilon_t^X) = \Sigma_\varepsilon^X$.

Due to the large number of time series, we will estimate the model using principal components for the data matrix $X = (X_1, \dots, X_T)'$ of dimension TxN, following Milan and Whittaker (1995). Then, retaining the r principal components we will have an estimate of the common factors F_t. Subsequently, we will calculate confidence intervals for which variable loadings are significantly different from zero following Bai and Ng (2006). Once we have the significant common factors obtained through principal components (hereafter PC), we will include them in the proposed structured augmented dynamic factor model.

Additionally, we will explore an alternative method for reducing our macroeconomic database. This involves estimating common factors using Partial Least Squares (PLS). The next chapter will examine this alternative method.

1.2. Oriented factors by Partial Least Squares

We also propose to reduce our macroeconomic database by estimating common factors using Partial Least Squares (PLS) following Wold (1966), Fuentes *et al.* (2015), Kelly and Pruitt (2015), and De Juan *et al.* (2023). This alternative allows us to select the common factors that maximise the sample variance and that have a high correlation with the target (see Hastie *et al.* (2009) in this regard), as opposed to principal components, which only consider the first characteristic. In this way, PLS allows us to orient the factors towards premature mortality by gender.

Therefore, the objective of PLS regression is to predict Y (key variable) from X (macroeconomic indicators) and to describe their common structure. This prediction is achieved by extracting a set of unobserved orthogonal components, called latent factors, based on the covariance between X and Y that have the best predictive power. PLS estimates these latent factors from the following successive decomposition of the eigenvalues of the X and Y matrixes:

$$M^{(i)} = X^{(i)\prime} Y^{(i)} Y^{(i)\prime} X^{(i)} \tag{3}$$

With $i = 1, \dots, r$. To extract the first factor, we start from $i = 1$, where we define $X^{(1)} = X$ and $Y^{(1)} = Y$, so that we form the matrix $M^{(1)} = X'YY'X$. We extract the first eigenvector of $M^{(1)}$ and determine the first PLS factor by linearly combining the variables in X using this first eigenvector of $M^{(1)}$. To extract the following PLS factors, $X^{(i)}$ will be composed of the residuals of the simple regressions of each of the predictors in X on the (i-1)-th PLS component, and $Y^{(i)}$ will be composed of the residuals of the target variable on the (i-1)-th PLS component. Subsequently, we will extract eigenvector of higher rank from $M^{(i)}$ and form the i-th PLS component as the linear combination of the variables in $X^{(i)}$ using that eigenvector of $M^{(i)}$. Successively, we repeat this procedure until the last factor is extracted. We will perform this procedure twice, once for the male case and once for the female case.

Once we have identified the common factors related to our target variable, PYLL, we will incorporate them into the proposed structured augmented dynamic factor model, as an alternative to the principal components (PC). The results obtained will be presented in the following section.

III.3. Results

This section presents the key findings derived from the application of the proposed methodology. Firstly, the results of extracting common factors from our macroeconomic database will be outlined, employing principal components in conjunction with a dynamic model. Secondly, we will discuss the factors identified through the Partial Least Squares (PLS) technique, which are specifically aligned with our target variable. Subsequently, the selection of individual variables will be addressed, focusing on those that exhibit the highest correlation with our target variable, within the framework of the structured augmented dynamic factor model (SADFM). Finally, we will present the results of the SADFM estimation across its three specifications: REG, R-FM, and the unrestricted full SADFM, designated as U-REGFM. This analysis will initially utilise principal components (PC) and subsequently PLS. The results will be examined for both male and female populations.

III.3.1. Results of DFM for the macroeconomy

We estimated the number of common factors following the ABC criterion of Alessi *et al.* (2010), which is a revision of the procedure proposed by Bai and Ng (2002). The final number of factors, $\hat{r}^{T}_{c;n}$, is 3. The stability of this estimate has been assessed using the empirical variance S_c, and the results support the robustness of our selection to sample size.

We have estimated the dynamic factor model for the Spanish macroeconomic indicators following Milan and Whittaker (1995) and De Juan *et al.* (2023). We obtain the factors by principal components (PC). Using Bartlett's method (Bartlett, 1937, 1938) we create new variables containing predictions of the scored factors. Figure 2 shows the eigenvalues associated with the factors obtained in decreasing order (Cattell, 1966), and again we can see how the graph suggests that we retain three factors. We can see that Factor 1 has the highest eigenvalue (51.07), explaining 28.69% of the variance, being the most significant factor. While Factor 2 explains 12.52% of the variance and Factor 3, explains 9.16%.

Figure 3 shows the evolution of the three common factors estimated. If we look at the evolution of Factor 1, we can identify similarities with the Spanish economic cycle. It reflects the recession of the 1990s, followed by a period of economic expansion, then the Great Recession in 2008 and its subsequent detrimental impact on the Spanish economy, as well as the negative effect of the pandemic and COVID-19 confinement on the economy in 2020. Conversely, Factor 2 exhibits an inverse relationship to Factor 1, increasing when Factor 1 decreases. Meanwhile, the evolution of Factor 3 could be capturing different or additional aspects of the economic environment. This Factor displays a demonstrating sustained growth throughout the 20th century, followed by a decline during the Great Recession and a partial recovery leading up to the COVID-19 pandemic.

The estimated loadings associated with the Factor 1 are shown in Figure 4. In this figure we can observe that Factor 1 is clearly related to the economy due to its high positive loadings on variables measuring GDP, consumption, output by sector, international trade, investment and employment. These variables are fundamental for assessing a country's economic performance. Some variables related to emissions by economic activity are also included. The variables with more negative loadings are mainly associated with short-term unemployment and external finances. Therefore, we can conclude that Factor 1 comprehensively represents the most critical aspects of the Spanish economy.

Figure 5 shows the estimated loadings associated with Factor 2. It is interesting to note how variables that do not have loadings in Factor 1, do have loadings in Factor 2. It is observed that variables such as average wages in different sectors, mainly construction, and government spending have a high positive loading on Factor 2. This indicates that Factor 2 is closely related to labour economics, reflecting wage differentials and employment in different economic sectors; and to economic policy, specifically to government spending in different areas, such as education, and other public services that affect overall economic welfare.

The variables with the most negative loadings are primarily linked to adverse environmental conditions, a smaller proportion of the working population in productive sectors, and increased challenges associated with savings and old-age dependency. Therefore, this set of variables is essential for evaluating Spain's competitiveness. They provide a comprehensive view of the economic, labour, social, and environmental factors that influence a country's ability to compete on a global scale.

Finally, Figure 6 shows how Factor 3 integrates socio-economic and environmental variables, covering aspects such as employment, demographic structure, government performance, urbanisation, sustainability and labour costs. It is interpreted as a mixed indicator that assesses economic growth through employment and labour costs, demographic transition towards greater urbanisation, and environmental sustainability in relation to carbon emissions. Variables with negative loadings include public debt, long-term unemployment, rural population and economic damage from carbon dioxide. On the other hand, positive loadings include government expenditure on health and public services, length of hospital stay, and labour costs in key sectors such as public administration, education, health, energy industry and agriculture.

In summary, the factors obtained through principal component analysis (PC) are related to the context of the Spanish economic cycle in the case of Factor 1 (hereafter f1). Factor

2 (hereafter f2) reflects Spain's competitiveness, while Factor 3 (hereafter f3) has a mixed composition. In the subsequent section, we will explore the oriented common factors and evaluate whether or not they demonstrate similarities with those derived from principal component analysis.

III.3.2. Results of oriented factors

The factors obtained by PLS (fpls in advance) are specifically oriented towards our target variable, premature mortality by gender, which allows the extracted factors to be more relevant for the prediction of premature mortality. A noteworthy feature of this approach is that it allows us to identify similarities and differences between factors oriented towards premature mortality in males (fplsM in advance) and females (fplsF in advance) in Spain.

Table 2 reflect the pairwise correlations between our target variable, potential years of life lost, and the common factors estimated by PC and PLS. The purpose is to examine the similarities and differences between these factors and how they relate to premature mortality.

The most noteworthy finding is that oriented factor 1 has the highest correlation with PYLL for both genders. For males, the correlation is -0.78 between PYLLM and fplsM1, while for females it is -0.62 between PYLLF and fplsF1, indicating that fpls1 and premature mortality move in opposite directions. However, the correlation between premature mortality and oriented factors 2 (fpls2) and 3 (fpls3) is positive, as well as the first shows a slightly higher correlation with premature mortality compared to the last. Interestingly, for these oriented factors the correlation with premature mortality is higher for females than for males, in contrast to oriented factor 1 (fpls1), where the correlation is higher for males. This shows the first distinction between genders.

When we take into account which macroeconomic variables compose the oriented factor 1, we find that fpls1 is closely linked to economic fluctuation. This factor has positive loadings on Gross Domestic Product (GDP in advance) and other economic variables, especially those related to the services sector, such as Gross Value Added (GVA), employees and wage earners in this sector, as well as exports and imports of goods and services and household consumption. Negatively loaded are variables such as length of hospital stays, exposure to particle matter (PM2.5) pollution, per capita emissions of volatile organic compounds and carbon monoxide, urban concentration in large agglomerations, and per capita consumption of fat and calories. Figure 7 shows how the evolution of this factor reflects the Spanish business cycle, for both genders.

On the other hand, oriented factor 2 has positive loadings on gender inequality index, alcohol consumption, household current expenditure on health, greenhouse gas emissions and air pollutants, and economic variables related to construction and industry, such as GVA, employed and wage earners in these sectors. Negative loadings are associated with variables such as unemployment (including short-term and long-term unemployed, unemployment rate and registered unemployment), as well as with operating subsidies, current transfers, financing capacity, the number of pupils in primary and secondary education, and renewable energy consumption. The composition of this factor and its evolution, depicted in Figure 8, follow dynamics of change in the living conditions and environment of the Spanish population linked to the economic cycle.

On the other hand, the evolution of oriented factor 3, shown in Figure 9, presents a more stable trend that could be related to aspects of economic development and competitiveness, as positive burdens are associated with social and environmental variables, such as the Gini Index, CO_2 emissions, perfluorocarbon emissions and tobacco consumption, average age at childbearing and AIDS incidence. While, the negative loadings are related to indicators of agriculture and energy sector, such as GVA, unit labour cost, employees and wage earners in these sectors. There are also relationships with public health variables, such as fruit consumption, the number of doctors and pharmacists and the vaccination rate against diseases such as tetanus.

If we now focus on the relationship between the common factors obtained from the principal components analysis and premature mortality, the results indicate that the correlations are significantly lower than that observed whit the oriented factors. Specifically, factors 1 and 2 exhibit negative correlations with premature mortality in both genders, although this relationship is considerably weaker in male compared to female. Conversely, a positive correlation is observed with factor 3. This suggests that favourable general economic conditions and the high competitiveness of the country are associated with a reduced loss of years of life.

If we analyze the correlation between the factors by PC and by PLS, we obtain a strong and positive relationship between Factor 1 and the oriented factor fpls1, which reflects a coherence in the factor composition, since they both reflect an important part of the Spanish economic cycle. While the relationship with Factor 2 and Factor 3 is less evident and suggests that these factors have different compositions.

The variability in correlations highlights how oriented common factors can identify differential influences that are not evident in the other factors. Variables such as '$PM_{2.5}$ air pollution, mean annual exposure' and others related to environmental degradation, that do not load on the factors obtained by PC, consistently cluster on the same factor for both genders in the PLS analysis, which underlines the importance of the results obtained through this approach.

Finally, it is important to note that there are no significant differences in the composition of male- and female-oriented factors, as demonstrated by the strong correlations observed between them. Despite the similarity in the composition of the factors, their influence may differ between genders, indicating possible variations in the way males and females are affected.

III.3.3. Variable selection for premature mortality

Instead of simplifying all the macroeconomic information for Spain through three common factors, another option is to choose a small number of economic indicators that can explain premature mortality in males and females. Crucially, it is not feasible to estimate a model that includes all variables as individual regressors because the number of variables (N) is much larger than the number of observations (T). Therefore, we have run N simple PYLL regressions (male and female case) on each of the macroeconomic variables (x_t), and calculated the N coefficients of determination (R^2) of these estimated models. The coefficients of determination are presented in Figure 10. It is observed that certain individual macroeconomic variables show a significant correlation with the growth rate of PYLL, with notable variations according to gender.

The highest R^2 coefficients by gender correspond to the variables shown in Table 3. For males, the variables with the highest correlations with premature mortality are exposure to $PM_{2.5}$ air pollution and Exports of Services. However, despite having the highest correlations with male's health, these variables demonstrate a significantly greater correlation with premature mortality in females. For females, the Human Development Index (HDI) and average length of hospital stay are the variables with the highest correlations with premature mortality, and these correlations are considerably higher than those observed for males. This indicates that, although some variables are highly correlated with premature mortality in both genders (specifically exposure to $PM_{2.5}$ and the average length of inpatient care) their impact is generally more pronounced in females.

In order to construct our structured augmented dynamic model, we conducted tests by regressing the aforementioned variables on potential years of life lost. To determine which variables to include as individual indicators, we will select those indicators that exhibit the highest explanatory power.

Table 3 presents these results, where the variable that remains constant in all specifications is $PM_{2.5}$ exposure for males, and the HDI for females, as these are the variables most correlated with premature mortality for each gender. Subsequently, for both genders, the most highly correlated secondary and tertiary variables are added to the variables mentioned above, as detailed in Table 3.

For the male case, when we use only one macroeconomic indicator ($PM_{2.5}$ exposure), we find that the R^2 is 0.32, and this variable is significant and positive, indicating that an increase in $PM_{2.5}$ exposure is associated with an increase in years of life lost. When we add length of hospital stay to the model, the R^2 increases to 0.38, and both indicators turn out to be significant and positive. However, when we introduce exports of services as a third explanatory variable, it does not show significance and the R^2 only marginally increases to 0.39. Therefore, we conclude that the preferred specification for males is the one that includes $PM_{2.5}$ exposure and length of hospital stay.

For the female case, when considering only HDI as a macroeconomic indicator, the model shows an R^2 of 0.50, with HDI being significant and negative. This suggests that an increase in HDI is associated with a decrease in premature mortality. When incorporating $PM_{2.5}$ exposure into the analysis, the R^2 increases to 0.56, and both indicators become significant (HDI remains negative and $PM_{2.5}$ exposure becomes positive). However, when length of hospital stay is added as a third variable, it does not contribute significantly to the model and the R^2 remains unchanged. Therefore, we conclude that the preferred specification for females is one that includes HDI and $PM_{2.5}$ exposure.

Once we have obtained the selected individual variables for both genders, along with the results derived from the common factors, we proceed to estimate the Structured Augmented Dynamic Factor Model (SADFM) in its three variants. In this regard, we note that the first variant is a pure structural regression model, as it includes only the individual variables, referred to as REG. The second variant is the restricted version of the structural model, which includes only the common factors extracted from the macroeconomic database, known as R-FM. The third variant is the full structural model, which incorporates both the common factors and the individual macroeconomic variables, referred to as U-REGFM. The results are presented in the following section.

III.3.4. Results of the structural model

The results of the SADFM estimation are presented in Table 4, where below the estimated coefficients the robust t-ratios are reported in parentheses, the last rows show the R^2 of the estimated models, the Durbin-Watson (DW) test and the Breusch-Godfrey (BG) test for autocorrelation, and the Breusch-Pagan (BP) test for heterogeneity.

The estimation results indicate that the estimated coefficients of the individual macroeconomic variables are statistically significant in all versions of the model in Panel I (SADFM by principal components), conserving the sign and in some cases increasing their effect (β_{ICL} y β_{HDI}) when we move from the model without common factors (REG) to the full model without restrictions (U-REGFM). The sign obtained tells us that an increase in $PM_{2.5}$ exposure and length of hospital stay increases premature mortality, while a higher HDI is beneficial for the health of the female population (reduces premature mortality). We found differences between males and females. The first is that the second individual indicator is not the same for both genders, and the second is that $PM_{2.5}$ exposure has a greater effect on the health of males.

We also find that the coefficient of the common factors is statistically different from zero and positive only for factor 3 in the female case, when the restricted version of the structural model (R-FM) is considered. This indicates that when factor 3, related to the mix of socioeconomic and environmental variables, increases, the health of the female population decreases.

Paying attention to the explanatory power of the models, it is observed that the individual estimation of the common factors by PC has an insignificant explanatory power, while the explanatory power does not vary from the REG model to the full model (the R^2 of the REG and U-REGFM model are 0.388 and 0.557 males, 0.44 and 0.58 females, respectively). In addition, the autocorrelation and heterogeneity tests indicate that in the REG and U-REGFM models there is insufficient evidence to reject the null hypothesis of no autocorrelation and homoscedasticity, while in the restricted model, the presence of heteroscedasticity is observed.

If we compare the above results with those obtained when using the common factors oriented to premature mortality by gender, we can observe, in Panel II, how the explanatory power of the models is considerably increased in the restricted model and in the complete model (R^2 around 0.85 in all cases). And that the tests of non-autocorrelation and homoscedasticity do not indicate evidence against the null hypothesis for any of the models analyzed, which guarantees the validity of the estimates, and the results obtained.

The first result to highlight in this line is that the coefficients of the individual macroeconomic variables change drastically and become non-statistically significant in the full model with PLS oriented factors (U-REGFM).

And second, that all coefficients (R-FM and U-REGFM specifications) of the oriented factors are statistically significant for both genders, and maintain the sign, giving robustness to the results. The sign of the first oriented factor (fpls1) is negative (-0.14/-0.11 by male/female case), indicating that when the evolution of the Spanish economy is favorable, premature mortality is reduced, but when the economy suffers from adversities, such as a recession, the negative effects are reflected in an increase in premature mortality. However, the sign of the second and third factors is negative, indicating that when changes in living conditions and environmental aspects of economic development and competitiveness are modified, premature mortality varies in opposite direction.

Thus, we can conclude that the oriented common factors have a very high explanatory power for premature mortality compared to the common factors that are not oriented toward the target variable. As well as, given that the model that only includes the individual economic indicators has a much lower explanatory power than the models that include the targeted factors, we conclude that the optimal model to explain premature mortality is the restricted R-FM by PLS model.

It is important to note that we observe gender differences in the effect of the oriented factors on our target variable, this difference between genders is statistically significant for oriented factor 1 and 2, but not for factor 3, as indicated by the F-statistics obtained from the regression analysis. It is observed that the effect of the first oriented factor is greater for males than for females, while the effect of the second is the other way around, lower for males than for females. This tells us that the health of males is more affected by the evolution of the economic cycle than the health of females. While changes related to adverse living conditions impact female's health more significantly than male's health.

III.4. Discussion

The results of this study provide solid evidence linking premature mortality with the common oriented factors obtained from 178 macroeconomic variables in Spain. This difference between factors obtained by PC and oriented factors by PLS has been previously noted, as indicated by De Juan *et al.* (2023).

The high explanatory power suggests that the common factors considered in the analysis play a key role in understanding the differences in premature mortality by gender, reinforcing their relevance in the design of public health policies. Although the composition of the factors is not different for males and females, their impact on premature mortality differs by gender.

It has been observed that the Spanish economic cycle (shown in factor 1), especially based on the service sector, has an inverse relationship with the evolution of premature mortality. The data indicate that the premature mortality rate follows a countercyclical pattern, as it is more associated with chronic diseases, accidents and suicides. During periods of recession, especially during the Great Recession, cuts in public spending on health made access to medical services more difficult, which increased inequality in their availability. This situation resulted in the postponement of important treatments and diagnoses due to economic constraints, which, in turn, resulted in an increase in premature mortality, as reflected in our results. Significant increases in premature deaths from intentional violence have also been documented during the 2008 recession in Europe, as noted by Stuckler *et al.* (2009).

It is highlighted that males and females may experience the effects of economic cycles on their health differently. A gender-differentiated impact is observed, indicating that although males may be more affected by business cycle fluctuations compared to females, both genders experience an increase in premature mortality during recessionary times. It has been observed that males tend to be more affected in terms of mortality and mental health, due to job loss and stress, as also previously indicated by Edwards (2008) and Sánchez-Recio *et al.* (2020). While females take on additional responsibilities in unpaid care work due to welfare cuts and privatization, while they continue to face discrimination in the labor market and in access to resources and decision-making centers, as indicated by Gálvez and Rodríguez-Modroño (2016), which also affects their health negatively.

In this line, it is observed how changes in living conditions and the environment linked to the economic cycle also affect premature mortality (collected in the oriented factor 2). The results indicate that changes towards increasing gender inequality, alcohol consumption, air pollution and emissions, and the growth of the construction sector have a negative impact on the health of the population, as they influence the increase in premature mortality. Unemployment, on the other hand, has a positive impact.

Disaggregation between males and females shows us how female health is more influenced by the effects of these changes, previously also observed by Veas *et al.* (2021), for OECD countries. Gender disparities in labour participation, political and economic power influence the health of females throughout their aging, as found for Europe by Leão *et al.* (2024). In particular, changes in living conditions due to the Great Recession have disproportionately affected disease prevention in females, as noted by Dave and Kelly (2012) and García-Mayor *et al.* (2021) in the Spanish context. The results also reflect an unequal effect of risk factors such as excessive alcohol consumption and smoking on mortality by gender, also seen in Mackenbach *et al.* (2015).

It is also highlighted from the results that changes in environmental conditions, related to worsening air quality, are significantly affecting respiratory health in Spain, as also indicated by Fernández-Navarro *et al.* (2017). Exposure to air pollution generated by industrial facilities, exposure to high concentrations of Greenhouse Gases, and to final particulate matter ($PM_{2.5}$) increases health burdens, leading to higher mortality rates, as observed in our results. This has been previously documented in studies in Europe (Doherty *et al.*, 2017) and Spain (Ostro *et al.*, 2011; Marval and Tronville, 2022).

Factor 2 also includes effects coming from the evolution of the construction sector. Although fatal accident rates have decreased in Spain in the last decade, especially during the great recession, this sector continues to present the worst record in occupational accidents in Spain, therefore, as our results show, it is to be expected that when this sector is booming, premature mortality related to accidents increases, while this type of accidents are reduced in times of recession. Previously some authors have pointed out these facts, such as Camino López *et al.* (2008), Li *et al.* (2015) and Lozano-Díez *et al.* (2019) for Spain.

This factor also shows how a higher unemployment rate positively affects the health of the Spanish population. In the sense that, during recessions, people have more free time for healthy activities such as exercise and rest, as well as a reduction in occupational stress by reducing the demands of work, thus contributing to an improvement in well-being and lower mortality. This phenomenon has also been highlighted by several authors in different countries, such as Ruhm (2005) for the United States; Tapia-Granados (2005, 2007) for Europe; and Regidor *et al.* (2014) for Spain, who have observed similar effects in their studies on the relationship between recessions and mortality.

Regarding the impact of oriented Factor 3, which pertains to aspects of economic development and competitiveness, we find that it has a direct effect on premature mortality. This indicates how health inequalities in income, unhealthy living habits (tobacco consumption) and adverse environmental conditions have a negative effect on health, as has also been highlighted in the literature. See Van Doorslaer and Koolman (2004), Oliva-Moreno *et al.* (2019) and Gavurova *et al.* (2021) in this regard. In contrast, greater development of the agricultural and energy sectors, greater access to health care and higher fruit consumption tend to reduce premature mortality, previously also highlighted by Martínez-González *et al.* (2012).

Although gender differences are not as evident in the impact of factor 3 targeting on premature mortality, such disparities persist. For example, females experience greater health benefits as their socioeconomic status improves, as previously also seen Dahlin and Härkönen (2013) and Gomez-Baya *et al.* (2020). A marked increase in premature mortality among females associated with smoking is also observed, while it has significantly decreased among males. See Oliva-Moreno *et al.* (2019) and Rey-Brandariz *et al.* (2022) for further reference.

However, there is evidence of greater homogeneity in consumption patterns between genders in fruit consumption, with an increase in intake by males. Despite this equality, variations in consumption continue to be influenced by the economic situation. In contexts of higher unemployment, both genders tend to reduce their consumption of healthy foods and increase consumption of unhealthy foods, while in more favorable situations, both genders consume a greater variety and quantity of fruits (Dave and Kelly, 2012). This dynamic in consumption is crucial, since it is associated with improvements in the health of the Spanish population, as it also points out Balboa-Castillo *et al.* (2011) and Martínez-González *et al.* (2012). This combined with a strong agricultural sector strengthens food security, boosts healthy diets and encourages a more sustainable approach, contributing comprehensively to reducing premature mortality by gender (WHO, 2015).

This analysis indicates that gender is a critical factor in understanding inequalities in mortality, as males and females face different health risks influenced by various factors such as economic cycle, lifestyle, socio-economic status and country development. This underscores the need for differentiated approaches to mitigate gender health disparities.

III.5. Conclusions

The aim of this paper has been to determine the determinants of health in the male and female population of Spain, and to investigate how they influence the health disparity between the two genders. To this end, we have considered premature mortality as an indicator of population health, since it mostly reflects potentially avoidable deaths. And we have selected a set of 178 macroeconomic time variables for Spain, covering the period 1990-2021, as possible determinants of health.

To achieve our objective, we considered a structural augmented factor Dynamic model (SADFM), which contains the most relevant macroeconomic indicators and unobserved common factors extracted from our set of macroeconomic variables. Initially, we identified three common factors using principal component (PC) analysis, and subsequently used the partial least squares (PLS) technique to obtain factors oriented towards our key variable, premature mortality disaggregated by gender.

It has been identified that the common factors extracted through principal component (PC) analysis correspond to the economic cycle, Spain's competitiveness and a mixed composition of socioeconomic and environmental variables. On the other hand, the oriented factors obtained through partial least squares (PLS) reflect the economic cycle based on the service sector, the dynamics of change in the living conditions and environment of the Spanish population linked to the economic cycle, as well as economic development and competitiveness. It is relevant to note that no differences are observed in the composition of these factors oriented between the male and female genders. However, among the most relevant individual macroeconomic indicators, it is observed that exposure to $PM_{2.5}$ particles affects both males and females, while the human development index (HDI) shows a higher incidence in females, and the length of hospital stay has a greater impact on males.

We have considered three approaches to the SADFM. The first is a pure structural regression model. The second is a version of the SADFM that includes only the common factors extracted from the macroeconomic database. The third is an unrestricted SADFM that incorporates both the common factors and the individual macroeconomic variables. These models have been applied considering gender disaggregation, both for the factors obtained by PC and for those extracted by PLS.

The results indicate that the oriented common factors explain more than 80% of the variability in premature mortality, for both genders; while the common factors obtained by PC analysis do not show significant explanatory power. The individual indicators selected show the expected signs (positive HDI effect on health, and negative effect associated with exposure to $PM_{2.5}$ particles and length of hospital stay) and are statistically significant. However, the best fitting model is the SADFM which includes exclusively the common factors oriented towards our target variable.

The estimation of the parameters of this model indicates that premature mortality is reduced when business cycle conditions, especially in the service sector, are favourable.

This positive relationship with health is more significant in males, suggesting that their well-being benefits more in times of economic growth. However, the dynamics of change in the living conditions and environment of the Spanish population, which are associated with gender inequality, alcohol consumption and emissions, have a negative effect on health. This adverse effect is especially pronounced in females, highlighting the urgency of considering gender disparities in public health policies.

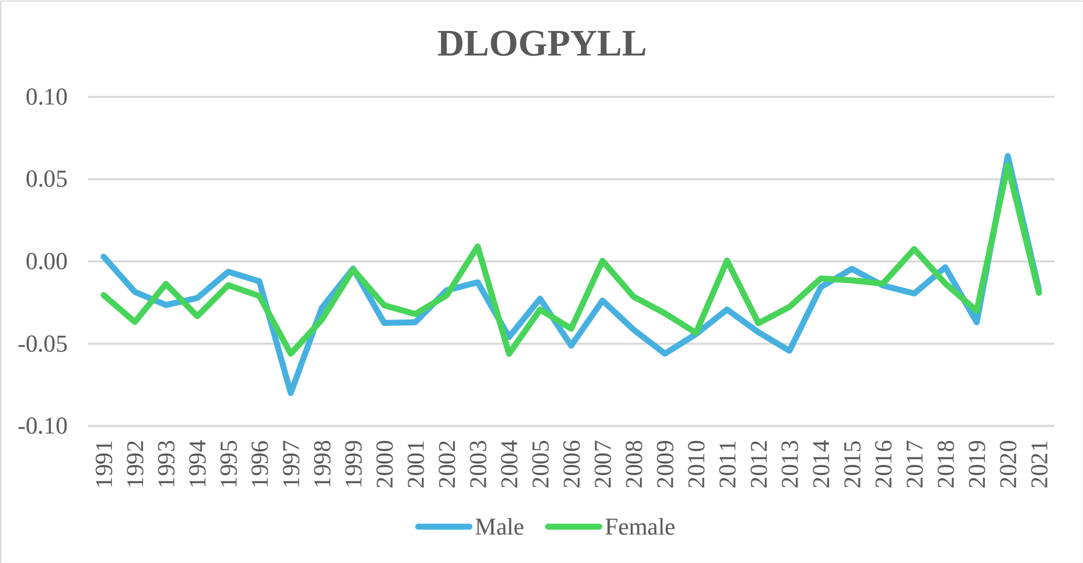
In addition, economic development and competitiveness, which are related to income inequality, also have negative effects on health. Although gender differences in this context do not reach statistical significance, their presence is latent and suggests that disparities between males and females deserve more intense attention in future research.

The results highlight that, although the composition of unobserved common factors extracted by PLS is the same for males and females, the effect of these factors on premature mortality varies by gender. In this sense, it is essential to address the various ways in which socioeconomic determinants impact the health of males and females, which will allow the implementation of more effective interventions to reduce premature deaths.

Although the Spanish health system is robust, it is imperative to continue efforts to reduce the gender gap in health outcomes through targeted policies. The formulation of policies that consider gender specificities in accessing health care and identifying health risks is essential to effectively address existing disparities. This includes paying attention to the social determinants that contribute to preventable deaths, which affect males and females differently. In conclusion, addressing these differences is crucial to making progress in reducing health inequalities and improving health outcomes in the general population.

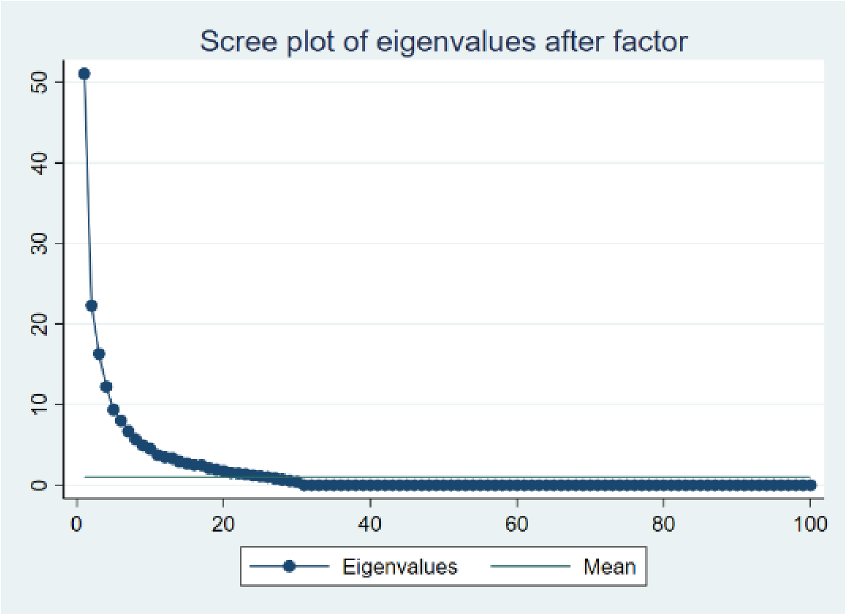
III.6. Figures and tables

Figure 1: Growth rates in Potential Years of Life Lost by Gender in Spain, 1991-2021



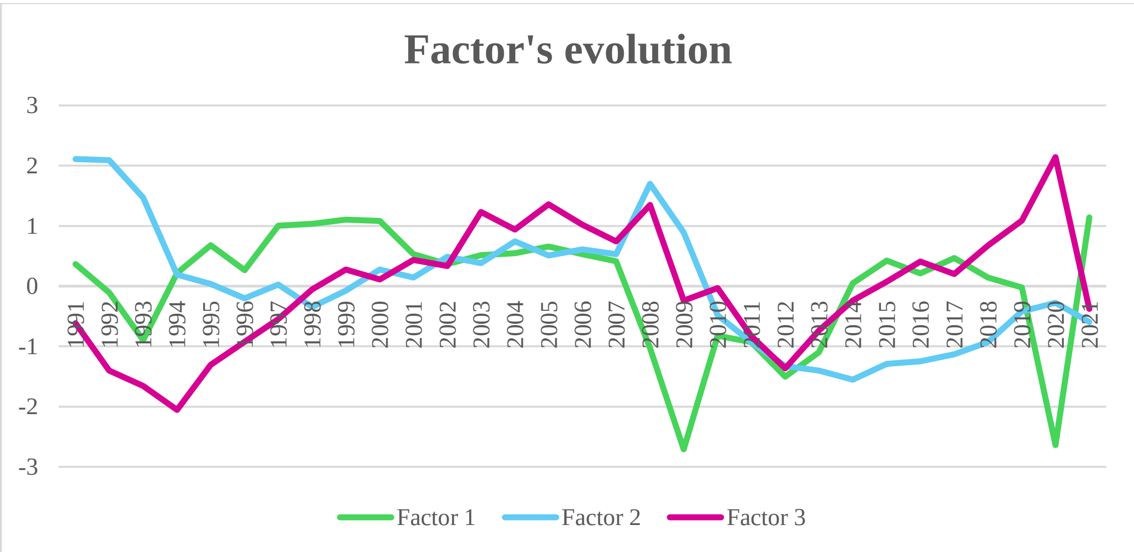
This figure shows the growth ratios of our key variable, broken down by gender.

Figure 2: Eigenvalues associated with the factors obtained



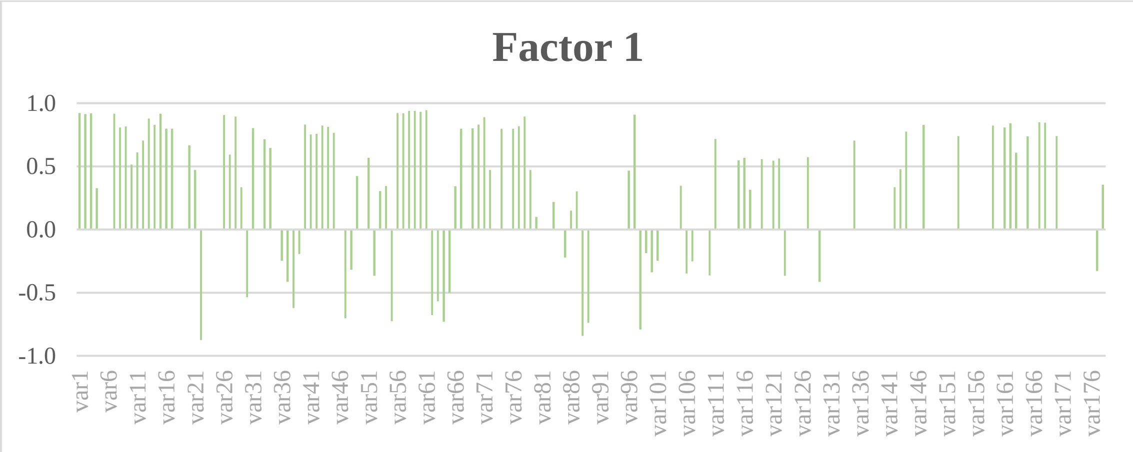
This graph captures the eigenvalues associated with the factors obtained, highlighting the variance explained by each factor and the cumulative contribution of these factors to the total variance in the data.

Figure 3: Evolution of the estimated common factors for Spain, 1991-2021



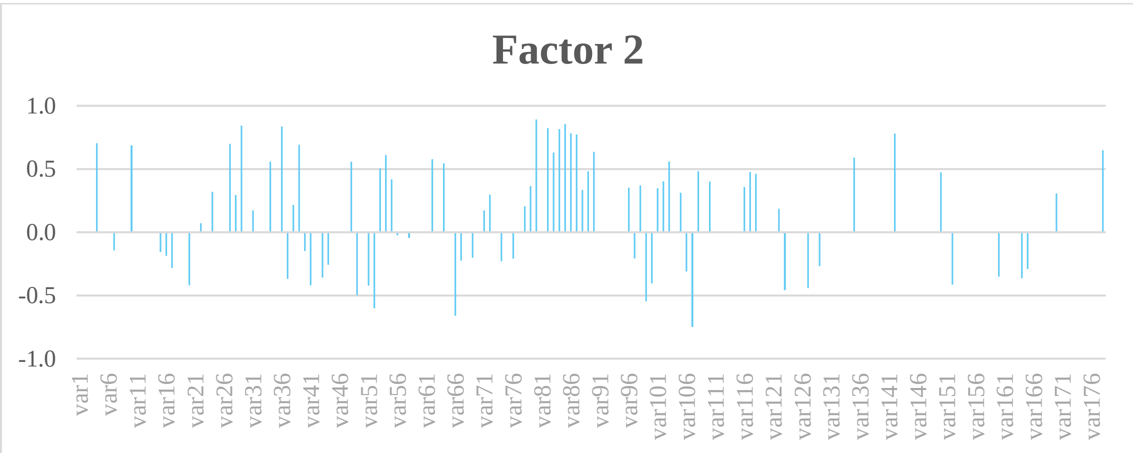
This graph illustrates the evolution of the estimated common factors for Spain from 1991 to 2021, derived from principal component analysis (PC).

Figure 4: Estimated loadings associated with Factor 1 for Spain, 1991-2021



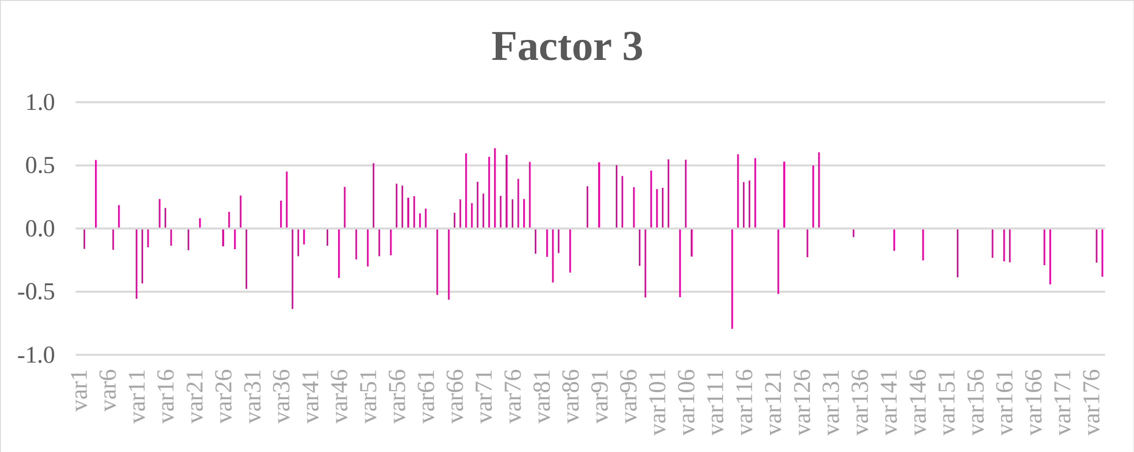
This graph illustrates the estimated loadings of the 178 macroeconomic indicators contributing to Factor 1 for Spain, over the period 1991 to 2021. Each segment represents the loading of the specific variables, reflecting their relative importance in shaping the underlying factor. Refers to the factor obtained by principal components.

Figure 5: Estimated loadings associated with Factor 2 for Spain, 1991-2021



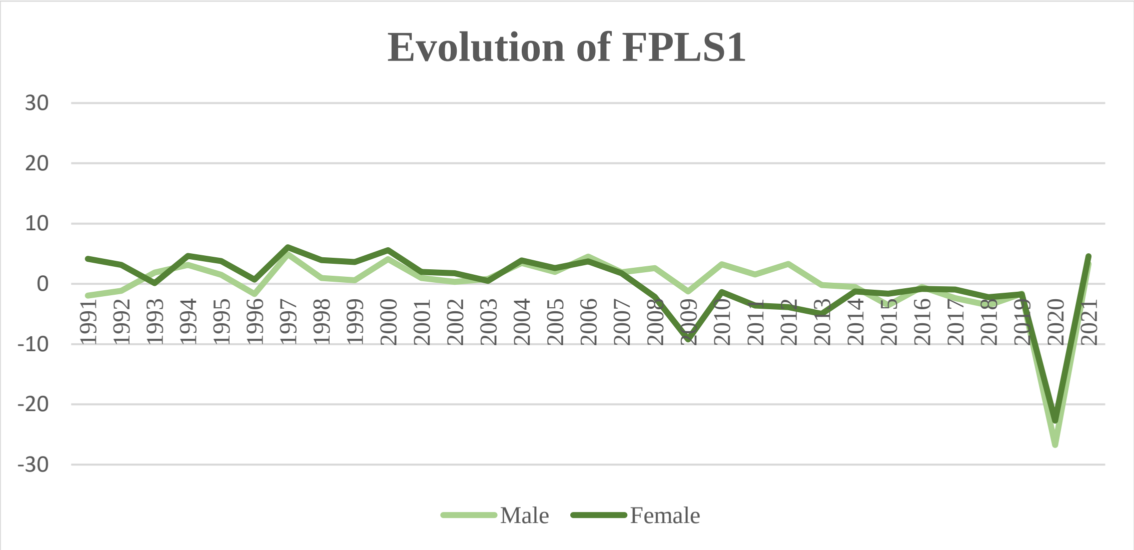
This graph illustrates the estimated loadings of the 178 macroeconomic indicators contributing to Factor 2 for Spain, over the period 1991 to 2021. Each segment represents the loading of the specific variables, reflecting their relative importance in shaping the underlying factor. Refers to the factor obtained by principal components.

Figure 6: Estimated loadings associated with Factor 3 for Spain, 1991-2021



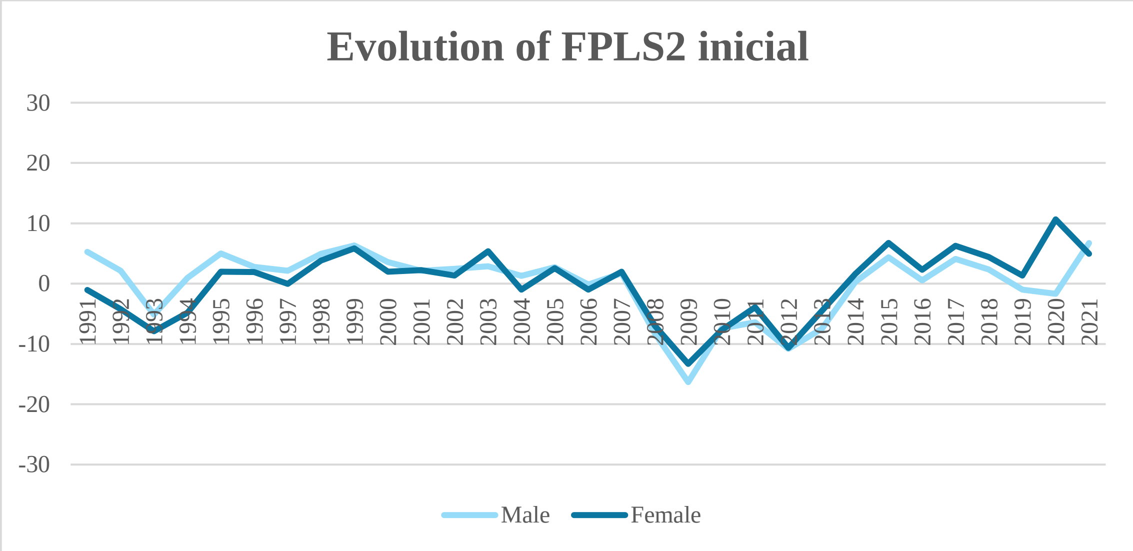
This graph illustrates the estimated loadings of the 178 macroeconomic indicators contributing to Factor 3 for Spain, over the period 1991 to 2021. Each segment represents the loading of the specific variables, reflecting their relative importance in shaping the underlying factor. Refers to the factor obtained by principal components.

Figure 7: Evolution of Oriented Common Factor 1 for Premature Mortality by gender, 1991-2021



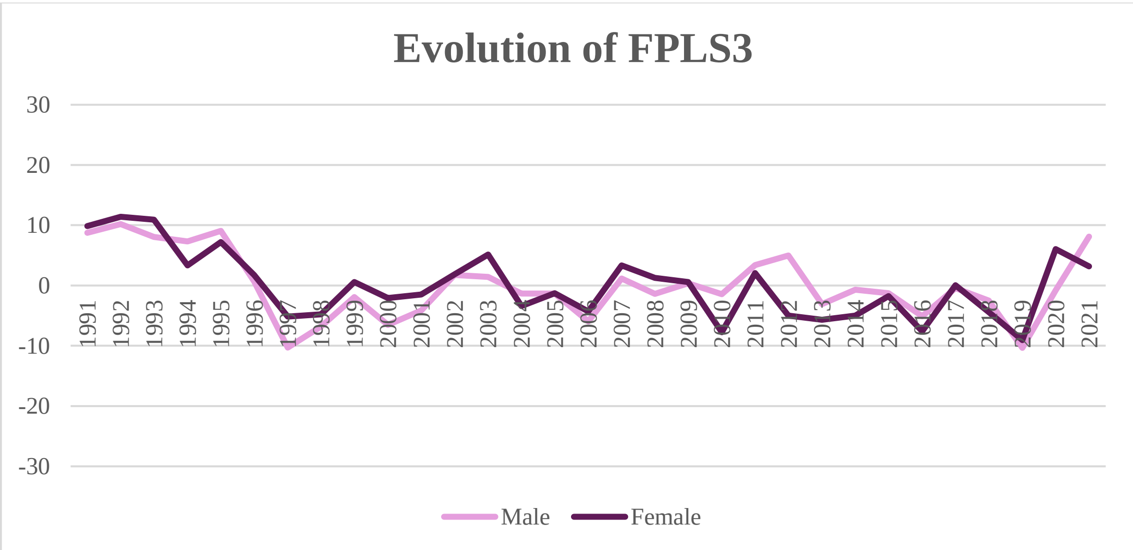
This graph displays the Oriented Common Factor 1 related to premature mortality in Spain, derived from Partial Least Squares (PLS) analysis, across the years 1991 to 2021. The graph is disaggregated by gender.

Figure 8: Evolution of Oriented Common Factor 2 for Premature Mortality by gender, 1991-2021



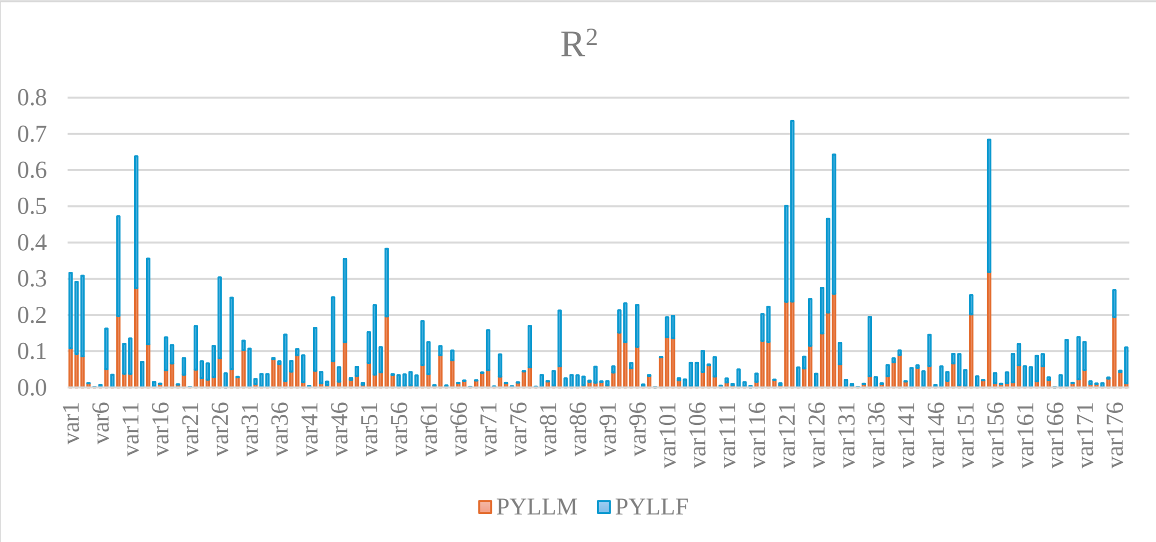
This graph displays the Oriented Common Factor 2 related to premature mortality in Spain, derived from Partial Least Squares (PLS) analysis, across the years 1991 to 2021. The graph is disaggregated by gender.

Figure 9: Evolution of Oriented Common Factor 3 for Premature Mortality by gender, 1991-2021



This graph displays the Oriented Common Factor 3 related to premature mortality in Spain, derived from Partial Least Squares (PLS) analysis, across the years 1991 to 2021. The graph is disaggregated by gender.

Figure 10: Representation of the coefficients of determination between PYLL by gender and Spanish macroeconomic variables



This graph illustrates the coefficients of determination (R^2) between Potential Years of Life Lost (PYLL), disaggregated by gender, and various macroeconomic variables in Spain. Each coefficient represents the proportion of variance in PYLL explained by the corresponding macroeconomic variable, highlighting the strength and significance of the relationships.

Table 1: Statistical characteristics of Potential Years of Life Lost

	PYLL		DLOGPYLL			
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Period	*1991-2021*	*1991-2021*	*1991-2021*	*1991-2021*	*1991-2019*	*1991-2019*
Mean	6,472.63	2,894.47	-0.02	-0.020	-0.03	-0.02
St.dev.	1,767.13	609.90	0.02	0.022	0.02	0.02
Skewness	0.30	0.50	1.04	1.368	-0.63	0.00
Kurtosis	1.70	1.96	6.81	6.678	3.13	2.56
JB	2.64	2.71	24.33	27.14	1.93	0.23
(p-value)	(0.27)	(0.26)	(5.2e-06)	(1.3e-06)	(0.38)	(0.89)
ADF	-2.31	-0.37	-5.16	-5.96	-4.88	-5.93
(p-value)	(0.17)	(0.98)	(0.00)	(0.00)	(0.00)	(0.00)

This table provides the statistical characteristics for the original 1990-2021 sample, the series in growth rates taking first differences from the logarithm of the original 1991-2021 series, and the same but for 1991-2019, to remove the effect of the COVID-19 pandemic. A table shows the mean, standard deviation (St. dev.), skewness, kurtosis, Jarque-Bera (JB) test for normality and Augmented Dickey-Fuller (ADF) test for stationarity. In parentheses is the p-value associated with the JB and ADF tests.

Table 2: Pairwise correlations between Spanish premature mortality, by gender, and PC factors and Oriented factors

	PYLLM	PYLLF	Factor1	Factor2	Factor3	fplsM1	fplsM2	fplsM3	fplsF1	fplsF2	fplsF3
PYLLM	1.00										
PYLLF	0.81	1.00									
Factor1	-0.09	-0.28	1.00								
Factor2	-0.05	-0.19	0.00	1.00							
Factor3	0.23	0.33	0.00	0.00	1.00						
fplsM1	-0.78	-0.75	0.49	0.12	-0.37	1.00					
fplsM2	0.39	0.12	0.86	0.01	0.11	0.00	1.00				
fplsM3	0.34	0.17	-0.15	0.33	-0.56	0.00	0.00	1.00			
fplsF1	-0.44	-0.62	0.85	0.26	-0.32	0.82	0.54	0.05	1.00		
fplsF2	0.61	0.53	0.52	-0.30	0.49	-0.44	0.80	-0.25	0.00	1.00	
fplsF3	0.46	0.38	-0.09	0.63	-0.29	-0.22	0.18	0.79	0.00	0.00	1.00

This table shows the correlations between gender-disaggregated premature mortality (PYLLM, PYLLF), the factors obtained by CP (Factori with i=1,2,3), and the oriented factors obtained by PLS. fplsMi with i=1,2,3 refers to the factor oriented towards premature mortality for males, while fplsMi with i=1,2,3 refers to the factor oriented towards premature mortality for females.

Table 3: Highest correlated variables with PYLL

Variable identification		**R^2**	
Index	***Variable Name***	***male***	***female***
var155	PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	0.32	0.37
var12	Exports of services- Constant prices 2015	0.27	0.36
var129	Hospital aggregates: Inpatient care average length of stay (all hospitals) (Days)	0.26	0.38
var122	Human Development Index	0.24	0.50
var121	Medical technology patents (Triadic, Inventor's country, Priority date)	0.24	0.26
var128	Hospital aggregates: Curative care average length of stay (Days)	0.21	0.26
var152	Non-methane Volatile Organic Compounds emissions (VOCs) (Kilograms per capita)	0.20	0.05
var9	GVApb Services-Constant Prices 2015	0.20	0.27

This table presents the coefficients of determination (R^2) for the variables most correlated with PYLL, differentiating between males and females. Variables with the highest correlation in both genders are included, including those with low correlation in one gender but high correlation in the other, such as Var152, which stands out for its strong relationship with PYLL in males despite its lower correlation with PYLL in females.

Table 4: Effect of $PM_{2.5}$, HDI, Hospital Stay and Exports of services on PYLL by Gender

	Male			Female		
	M-1	*M-2*	*M-3*	*F-1*	*F-3*	*F-4*
$\beta_{PM2.5}$	0.56***	0.41**	0.38*		0.29*	0.28*
	(3.69)	(2.43)	(2.03)		(1.92)	(1.82)
β_{HDI}				-0.70***	-0.53***	-0.43*
				(-5.36)	(-3.48)	(-2.01)
β_{ICL}		0.30*	0.23			0.15
		(1.77)	(0.91)			(0.73)
β_{EXP}			-0.13			
			(-0.50)			
R^2	0.32	0.38	0.39	0.50	0.56	0.56

The table presents the estimated coefficients (β) for the effects of $PM_{2.5}$ exposure, HDI, Inpatient care average length of stay and Exports of services on the dependent variables by gender (male and female) in three regressions (M-i with i=1,…,3 for male and F-i with i=1,...,3 for female). The values in parentheses indicate the t-ratios. ***, **, and * denote rejections at the 1%, 5%, and 10% significance levels, respectively. The coefficient of determination (R^2) is shown in the last row for each model.

Table 5: Estimation of Structural Augmented Dynamic Factor Model

	REG		R-FM		U-REGFM	
	Male	Female	Male	Female	Male	Female
			Panel I. SADFM by Principal components			
$\beta_{PM2.5}$	0.41** (2.43)	0.29* (1.92)			0.41** (2.34)	0.28* (1.75)
β_{ICL}	0.30* (1.77)				0.59** (2.33)	
β_{HDI}		-0.53*** (-3.48)				-0.67** (-2.77)
β_{f1}			-0.09 (-0.51)	-0.28 (-1.67)	0.23 (1.31)	0.15 (0.86)
β_{f2}			-0.05 (-0.29)	-0.19 (-1.15)	0.11 (0.65)	-0.07 (-0.50)
β_{f3}			0.22 (1.21)	0.33* (1.97)	-0.27 (-1.32)	-0.11 (-0.67)
			Information of the estimated models			
R^2	0.38	0.56	0.06	0.23	0.44	0.58
DW	1.77	1.96	1.65	2.11	2.32	2.03
BG	0.09	0.00	0.71	0.18	1.62	0.03
BP	0.29	0.39	7.70***	6.46***	0.13	0.71
			Panel II. SADFM by PLS			
$\beta_{PM2.5}$	0.41** (2.43)	0.29* (1.92)			-0.05 (-0.48)	-0.16 (-1.35)
β_{ICL}	0.30* (1.77)				0.07 (0.65)	
β_{HDI}		-0.53*** (-3.48)				-0.13 (-0.83)
β_{fpls1}			-0.14*** (-11.36)	-0.11*** (-7.64)	-0.14*** (-5.75)	-0.11*** (-3.66)
β_{fpls2}			0.07*** (5.67)	0.10*** (6.56)	0.07*** (5.53)	0.11*** (5.38)
β_{fpls3}			0.06*** (4.97)	0.07*** (4.72)	0.06*** (4.76)	0.08*** (4.81)
			Information of the estimated models			
R^2	0.38	0.557	0.87	0.821	0.88	0.84
DW	1.77	1.96	2.38	1.95	2.44	1.94
BG	0.09	0.00	1.28	0.02	1.80	0.03
BP	0.29	0.39	2.15	0.08	2.14	0.07

This table presents the estimation of the three versions of the structural model: a pure structural regression model (REG), the restricted version of the structural model that includes only the common factors extracted from the macroeconomic database (R-FM), and the full structural model that includes both the common factors and individual macroeconomic variables (U-REGFM). The values in parentheses indicate the robust t-ratios. ***, **, and * denote rejections at the 1%, 5%, and 10% significance levels, respectively.

Conclusiones (Spanish)

En esta tesis doctoral, se exploran las diferencias en el estado de salud de la población masculina y femenina de los países de la Organización para la Cooperación y el Desarrollo Económico (OCDE), así como las causas subyacentes que pueden influir en estos resultados.

En el primer capítulo se revela que la disminución en la mortalidad prematura en estos países, desde 1990 hasta 2017, es ligeramente más pronunciada en hombres que en mujeres. El análisis de convergencia realizado indica que la agrupación de los países en varios clubs no presenta diferencias significativas según el género. Sin embargo, las fuerzas que impulsan la creación de clubs de convergencia difieren notablemente entre hombres y mujeres. En particular, el índice de Gini tiene un efecto negativo en la creación de clubs tanto para hombres como para mujeres, lo que implica que, a medida que aumenta la desigualdad, disminuyen las probabilidades de pertenecer a un club con menor mortalidad prematura. El gasto sanitario tiene un impacto positivo en la creación de clubs para mujeres, mientras que el PIB influye positivamente y los daños causados por el dióxido de carbono (CO_2) negativamente en la creación de clubs para hombres. Además, la investigación revela que el proceso de mejora de la salud se ralentiza tras la Gran Recesión, evidenciando una heterogeneidad en sus efectos, ya que algunos países sufrieron graves pérdidas en sus niveles de salud tras dicho evento.

A partir de los resultados del primer capítulo, en el segundo capítulo nos centramos en el impacto de la degradación del medio ambiente en la salud, dado que es una variable clave en la creación de clubs. Vivir en áreas con altos niveles de emisiones de CO_2, y por tanto de contaminación, reduce la probabilidad de que las personas tengan una esperanza de vida prolongada o de pertenecer a un grupo con bajos niveles de mortalidad prematura. Para analizar dicha relación, en este capítulo hemos considerado la posible presencia de rupturas estructurales en las series, que pueden afectar a la relación entre medioambiente y salud en el largo plazo. Así como, para aportar robustez al análisis, también se han incluido el PIB y el gasto sanitario como variables de control. Los resultados indican que la relación entre degradación del medioambiente y salud se ve afectada por la Gran Recesión, y que difiere según el género considerado. Concretamente, la contaminación del aire afecta negativamente a la salud de ambos géneros, pero se observa un impacto mayor sobre la salud de los hombres. La desigualdad en los resultados de salud entre géneros se vio exacerbada por la Gran Recesión, de manera que el impacto perjudicial de la contaminación sigue siendo mayor para los hombres, lo que incrementa las disparidades de salud entre géneros. Estas disparidades también se observan en la relación entre crecimiento económico y salud. En este sentido, el crecimiento del PIB ejerce un efecto positivo más pronunciado en la salud de los hombres, tanto antes como después de la GR, lo que sugiere que este grupo se beneficia en mayor medida que las mujeres. En contraste, en lo que respecta al gasto sanitario, las disparidades de salud entre géneros se hacen evidentes únicamente después de la Gran Recesión, cuando el efecto positivo del gasto en salud es más pronunciado para las mujeres.

Además de los factores económicos y medioambientales, existen otros elementos sociales y socioeconómicos que influyen en la salud de la población. En el tercer capítulo, nuestro análisis se centra en identificar los factores que impactan la salud de la población de España, un país que se destaca por sus excelentes resultados en salud en comparación con otros miembros de la OCDE. Para ello, hemos considerado una amplia gama de indicadores económicos, socioeconómicos, medioambientales y sociales, para posteriormente extraer factores comunes, a fin de evaluar cómo las variaciones en estos indicadores influyen de manera dinámica en la salud de la población a lo largo del tiempo. Los resultados indican que, aunque la composición de estos factores es similar para hombres y mujeres, su impacto sobre la mortalidad prematura varía significativamente según el género considerado. Obtenemos que el primer factor, relacionado con la evolución del ciclo económico español, afecta en mayor medida a los hombres, lo que sugiere que los cambios en la actividad económica tienden a tener un mayor impacto en la salud masculina. El segundo factor, vinculado a las condiciones de vida y el entorno, tiene un efecto más pronunciado en las mujeres, lo que resalta la importancia del entorno social y físico en la salud femenina. Finalmente, el tercer factor, asociado al desarrollo económico y desigualdad, afecta de manera similar a ambos géneros, aunque con un impacto ligeramente mayor en las mujeres, lo cual sugiere que, a pesar de las similitudes en la influencia de este factor, las mujeres pueden ser más susceptibles a los efectos del desarrollo económico y la desigualdad.

En el marco del modelo dinámico estructural aumentado utilizado en el tercer capítulo, también se han considerado indicadores individuales que resultan pertinentes para el análisis y que evidencian disparidades de género significativas. En particular, de nuevo se observa que la exposición a materia particulada destaca por ejercer un impacto más pronunciado en la salud de los hombres, a pesar de que su efecto negativo afecta a ambos géneros. Por otro lado, el Índice de Desarrollo Humano se relaciona con un efecto más favorable en la salud de las mujeres, mientras que los días promedio de estancia en hospitales revelan una mayor incidencia negativa en la salud de la población masculina.

Los resultados obtenidos en los tres capítulos son consistentes y revelan patrones claros en la relación entre diversos factores y la salud, con un enfoque particular en las diferencias de género. En primer lugar, se establece que la contaminación del aire tiene un efecto negativo significativo sobre la salud, siendo este impacto más pronunciado en los hombres. Asimismo, la desigualdad se manifiesta como un factor adverso que afecta a ambos géneros, aunque con un impacto ligeramente más fuerte sobre la salud de las mujeres. En contraste, la actividad económica reflejada en el PIB se asocia con un efecto positivo en la salud, con un impacto más pronunciado en la población masculina. Finalmente, las crisis económicas, en particular la Gran Recesión, agravan las desigualdades en salud existentes y amplifican los efectos nocivos de la contaminación en la salud de la población.

También cabe destacar que los resultados obtenidos a nivel nacional corroboran los hallazgos obtenidos para la totalidad de los países de la OCDE. En este sentido, España se sitúa en línea con la media de la OCDE, lo que refuerza la validez de los resultados y su relevancia para futuros escenarios en salud.

En esta línea, la investigación ha logrado varios objetivos clave. En primer lugar, se han identificado disparidades significativas en los resultados sanitarios entre los países de la OCDE, lo que subraya la necesidad de que cada país colabore para fortalecer sus sistemas de salud y garantizar un acceso equitativo a servicios de salud de calidad, de manera que todos los países puedan avanzar hacia estándares similares en salud pública.

En segundo lugar, se ha demostrado que los factores económicos, sociales y socioeconómicos influyen tanto a nivel supranacional como nacional, lo que implica que las políticas de salud deben orientarse a reducir las desigualdades en salud, garantizando que todas las poblaciones, especialmente las más vulnerables, tengan acceso equitativo a recursos de salud y condiciones de vida que les permitan prosperar. Para lograrlo, es esencial que exista colaboración intersectorial entre áreas como salud, educación, trabajo y desarrollo social, abordando de manera integral los determinantes sociales que afectan la salud.

En tercer lugar, se ha evidenciado un impacto directo de la degradación ambiental en la salud, lo que resalta la urgencia de implementar políticas más estrictas que mitiguen este efecto adverso y fomenten la transición hacia energías limpias y sostenibles. Esta necesidad es particularmente apremiante en el contexto actual, donde el cambio climático representa un desafío significativo para la salud pública.

Por último, se han encontrado desigualdades en los resultados sanitarios entre géneros en diversos ámbitos, y se ha observado que las recesiones económicas exacerban estas disparidades. Esto subraya la necesidad de formular políticas de salud que aborden las particularidades y necesidades específicas de cada género. Asimismo, es fundamental que estas políticas se adapten a las condiciones económicas cambiantes para garantizar un acceso equitativo y proteger la salud de todos los grupos.

En resumen, el estudio demuestra una interconexión entre tres líneas prioritarias de la Agenda 2030: la salud, el crecimiento sostenible y el cuidado del medio ambiente, tanto a nivel nacional como supranacional. Estas relaciones están expuestas a cómo los países abordan la sostenibilidad económica y ambiental, y su impacto en la salud pública. Un aspecto clave es la disparidad de género en estas interrelaciones. Hombres y mujeres experimentan los efectos del crecimiento económico, la degradación ambiental y las políticas sanitarias de manera diferente, reflejando una brecha de género en la distribución de beneficios y perjuicios. Este patrón resalta la necesidad de comprender las especificidades de género al diseñar políticas que busquen alcanzar los objetivos de la Agenda 2030. Asimismo, es fundamental no pasar por alto los factores que influyen en las disparidades en salud, especialmente en tiempos de recesión económica, ya que estas crisis tienden a agravar dichas desigualdades. Por lo tanto, las políticas públicas deben ir más allá de un enfoque exclusivo en el crecimiento económico; es esencial que se complementen con políticas que integren una perspectiva de género, prioricen la equidad en la distribución de recursos y promuevan la protección del medio ambiente. Solo de esta manera se podrán alcanzar mejoras significativas y sostenibles en los resultados de salud, contribuyendo así al cumplimiento de los objetivos de la Agenda 2030.

Conclusions

This doctoral thesis explores the differences in health status between the male and female populations of countries within the Organisation for Economic Co-operation and Development (OECD), as well as the underlying causes that may influence these outcomes.

The first chapter reveals that the decline in premature mortality in these countries from 1990 to 2017 is slightly more pronounced for males than for females. The convergence analysis conducted indicates that the grouping of countries into several clubs does not show significant differences by gender. However, the forces driving the creation of convergence clubs differ markedly between males and females. In particular, the Gini index has a negative effect on the creation of clubs for both males and females, implying that, as inequality increases, the likelihood of belonging to a club with lower premature mortality decreases. Health expenditure has a positive impact on the creation of clubs for females, while GDP has a positive impact and carbon dioxide (CO_2) damage has a negative impact on the creation of clubs for males. In addition, the research reveals that the process of health improvement slows down after the Great Recession, showing heterogeneity in its effects, as some countries suffered severe losses in their health levels after the Great Recession.

Based on the results of the first chapter, the second chapter focuses on the impact of environmental degradation on health, as it is a key variable in the formation of clubs. Living in areas with high CO_2 emissions—and therefore high levels of pollution—reduces the likelihood of experiencing a prolonged life expectancy or belonging to a group with low levels of premature mortality. To analyse this relationship, in this chapter we have considered the possible presence of structural breaks in the series, which may affect the relationship between environment and health in the long run. In order to make the analysis more robust, GDP and health expenditure have also been included as control variables. The results indicate that the relationship between environmental degradation and health is affected by the Great Recession, and that it differs by gender. Specifically, air pollution negatively affects the health of both genders, but there is a greater impact on the health of males. The inequality in health outcomes between genders was exacerbated by the Great Recession, so that the detrimental impact of pollution continues to be greater for males, increasing health disparities between genders. These disparities are also seen in the relationship between economic growth and health. In this regard, GDP growth exerts a more pronounced positive effect on the health of males, both before and after RM, suggesting that this group benefits to a greater extent than females. In contrast, in terms of health spending, gender health disparities become evident only after the Great Recession, when the positive effect of health spending is more pronounced for females.

In addition to economic and environmental factors, there are other social and socio-economic elements that influence population health. In the third chapter, our analysis focuses on identifying the factors that impact the health of the population in Spain, a country that stands out for its excellent health outcomes compared to other OECD members. To do so, we have considered a wide range of economic, socio-economic, environmental and social indicators, and then extracted common factors to assess how variations in these indicators dynamically influence population health over time. The results indicate that, although the composition of these factors is similar for males and females, their impact on premature mortality varies significantly by gender. We find that the first factor, related to the evolution of the Spanish business cycle, affects males to a greater extent, suggesting that changes in economic activity tend to have a greater impact on male health. The second factor, linked to living conditions and environment, has a more pronounced effect on females, highlighting the importance of the social and physical environment on female health. Finally, the third factor, associated with economic development and inequality, affects both genders similarly, although with a slightly greater impact on females, suggesting that, despite similarities in the influence of this factor, females may be more susceptible to the effects of economic development and inequality.

Within the framework of the augmented structural dynamic model used in the third chapter, individual indicators that are relevant for the analysis and that show significant gender disparities have also been considered. In particular, it is again observed that exposure to particulate matter stands out as having a more pronounced impact on the health of males, despite the fact that its negative effect affects both genders. On the other hand, the Human Development Index is related to a more favourable effect on the health of females, while the average days spent in hospital reveal a greater negative impact on the health of the male population.

The results obtained in the three chapters are consistent and reveal clear patterns in the relationship between various factors and health, with a particular focus on gender differences. First, it is established that air pollution has a significant negative effect on health, with this impact being more pronounced for males. Inequality also emerges as an adverse factor affecting both genders, although with a slightly stronger impact on female health. In contrast, economic activity reflected in GDP is associated with a positive effect on health, with a more pronounced impact on the male population. Finally, economic crises, particularly the Great Recession, aggravate existing health inequalities and amplify the harmful effects of pollution on population health. It is also worth noting that the results obtained at national level confirm the results obtained for the OECD countries as a whole. In this sense, Spain is in line with the OECD average, which reinforces the validity of the results and their relevance for future health scenarios.

In this way, the research has achieved several key objectives. Firstly, it has identified significant differences in health outcomes between OECD countries, highlighting the need for countries to work together to strengthen their health systems and ensure equitable access to quality health services, so that all countries can move towards similar standards of public health.

Secondly, economic, social and socio-economic factors have been shown to influence at both supranational and national levels, implying that health policies should be oriented towards reducing health inequalities, ensuring that all populations, especially the most vulnerable, have equitable access to health resources and living conditions that allow them to thrive. To achieve this, it is essential that there is inter-sectoral collaboration between areas such as health, education, labour and social development, comprehensively addressing the social determinants that affect health.

Third, there is evidence of the direct impact of environmental degradation on health, underlining the urgency of implementing stronger policies to mitigate these adverse effects and to promote the transition to clean and sustainable energy. This need is particularly urgent in the current context, where climate change is a major public health challenge.

Finally, inequalities in health outcomes between genders have been highlighted in a number of areas, and economic downturns have been found to exacerbate these disparities. This underscores the need to formulate health policies that address gender-specific particularities and needs. It is also essential that these policies adapt to changing economic conditions to ensure equitable access and protect the health of all groups.

In summary, the study demonstrates an interconnection between three priority lines of the 2030 Agenda: health, sustainable growth and environmental protection, at both national and supranational levels. These relationships are exposed to how countries address economic and environmental sustainability and their impact on public health. A key aspect is the gender disparity in these interrelationships. Males and females experience the effects of economic growth, environmental degradation and health policies differently, reflecting a gender gap in the distribution of benefits and harms. This pattern highlights the need to understand gender specificities when designing policies that seek to achieve the goals of the 2030 Agenda. It is also crucial not to overlook the factors that influence health disparities, especially in times of economic downturn, as these crises tend to exacerbate such inequalities. Therefore, public policies must go beyond an exclusive focus on economic growth; it is essential that they are complemented by policies that integrate a gender perspective, prioritise equity in the distribution of resources and promote environmental protection. Only in this way can significant and sustainable improvements in health outcomes be achieved, thereby contributing to the achievement of the 2030 Agenda goals.

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Appendixes

Appendix I

This appendix contains the definitions of the variables used in the Chapter I.

Definitions:

Potential years of life lost is an indicator that summarizes premature mortality, providing an explicit way of weighting deaths occurring at younger ages, which may be preventable. The calculation of Potential Years of Life Lost (PYLL) involves summing up deaths occurring at each age and multiplying this with the number of remaining years to live up to a selected age limit (age 70 is used in OECD Health Statistics). In order to assure cross-country and trend comparison, the PYLL is standardized for each country and each year. The total OECD population in 2010 is taken as the reference population for age standardization. This indicator is presented as a total and per gender. It is measured in years lost per 100, 000 inhabitants (total), per 100,000 men and per 100,000 women, aged 0-69. Source: OECD Data

GDP per capita (constant 2017 international $), based on purchasing power parity, is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. GDP at purchaser's prices is the sum of gross value added by all resident producers in the country plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2017 international dollars. Source: World Data Bank

Gini Index is the index of inequality among the population of a country or region. The value of the Gini index is between 0 and 1, with zero being the maximum equality (all citizens have the same income) and 1 being the maximum inequality (all income is held by a single citizen). Source: World Data Bank

The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from zero to one and measures the productivity as a future worker of a child born today relative to the benchmark of full health and complete education. Source: World Data Bank

Unemployment refers to the share of the labor force that is without work but available for and seeking employment. The series is part of the ILO estimates and is harmonized to ensure comparability across countries and over time by accounting for differences in data source, scope of coverage, methodology, and other country-specific factors. The estimates are based mainly on nationally representative labor force surveys, with other sources (population censuses and nationally reported estimates) used only when no survey data are available. Source: World Data Bank

Immunization measles represents child measles immunization and measures the percentage of children aged 12-23 months who received the measles vaccination before 12 months or at any time before the survey. A child is considered adequately immunized against measles after receiving one dose of vaccine. Source: World Data Bank

Immunization polio is the rate of child immunization against polio measured as the percentage of children aged 12-23 months who received polio vaccinations before 12 months or at any time before the survey. A child is considered adequately immunized after three doses. Source: World Data Bank

Mortality CVD, cancer, or diabetes is the percentage of 30-year-olds who would die before age 70 from any cardiovascular disease, cancer, diabetes, or chronic respiratory disease, assuming he/she would experience current mortality rates at each age and would not die from any other cause of death (e.g., injury or HIV/AIDS). Source: World Data Bank

Maternal mortality is the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births. The data are estimated with a regression model using information on the proportion of maternal deaths among non-AIDS deaths in women aged 15-49, fertility, birth attendants, and GDP measured using purchasing power parities (PPPs). Source: World Data Bank

Diabetes prevalence refers to the percentage of people aged 20-79 who have type 1 or type 2 diabetes. It is calculated by adjusting to a standard population age-structure. Source: World Data Bank

Prevalence anaemia among children is the proportion of children under age 5 whose haemoglobin level is less than 110 grams per litre, adjusted for altitude. Source: World Data Bank

Prevalence overweight is the percentage of adults aged 18 and over whose Body Mass Index (BMI) is more than 25 kg/m2. Body Mass Index (BMI) is a simple index of weight-for-height, or the weight in kilograms divided by the square of the height in meters. Source: World Data Bank

Current Health Expenditure per capita is current health expenditure converted to international dollars using purchasing power parity (PPP) rates. Level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT, and stocks of vaccines for emergency or outbreaks. Source: World Data Bank

Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. The estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5. Source: World Data Bank

Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5. Source: World Data Bank

Voice accountability captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. The estimate gives the country's score on the aggregate indicator in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5. Source: World Data Bank.

Greenhouse gases emissions represent trends in man-made emissions of major greenhouse gases and emissions by gas. Data refer to total emissions of CO_2 (emissions from energy use and industrial processes, e.g. cement production), CH_4 (methane emissions from solid waste, livestock, mining of hard coal and lignite, rice paddies, agriculture and leaks from natural gas pipelines), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The variable is expressed in per capita terms. Source: OECD Data

Carbon dioxide damage measures the cost of damage due to carbon dioxide emissions from fossil fuel use and cement manufacturing. It is estimated at $30 per ton of CO_2 (the unit damage in 2014 US dollars for CO_2 emitted in 2015) multiplied by the number of tons of CO_2 emitted. Source: World Data Bank

Appendix II

This appendix contains the definitions of the variables used in the Chapter II, except for the definition of Potential Years of life lost, as we use the same key health indicator in Chapter I, II and III.

Definitions:

Gross Domestic Product (GDP) serves as the standard measure of the value added created through the production of goods and services in a country during a specific period. It not only gauges the income earned from such production but also quantifies the total expenditure on final goods and services (excluding imports). While GDP stands as the foremost indicator for capturing economic activity, it may not fully encompass people's material well-being, for which alternative indicators might be more suitable. This indicator is based on nominal GDP (also known as GDP at current prices or GDP in value) and is presented in different measures: US dollars and US dollars per capita (current PPPs). All OECD countries compile their data in accordance with the 2008 System of National Accounts (SNA). It is worth noting that this indicator is less optimal for temporal comparisons, as changes result not only from real growth but also from variations in prices and PPPs. Source: OECD Data.

Health expenditure (HEXP) reflects the ultimate consumption of health care goods and services, encompassing current health expenditure. This includes personal health care (curative care, rehabilitative care, long-term care, ancillary services, and medical goods) and collective services (prevention, public health services, and health administration), excluding expenditures on investments. Health care financing involves a combination of funding mechanisms, including government spending and compulsory health insurance ("Government/compulsory"), as well as voluntary health insurance and private funds, such as households' out-of-pocket payments, NGOs, and private corporations ("Voluntary"). The indicator represents the total financing and is measured in USD per capita (utilizing economy-wide PPPs). Source: OECD Data.

Carbon dioxide emissions (CO_2), predominantly produced through energy generation and utilization, constitute the largest proportion of greenhouse gases linked to global warming. Human-induced CO_2 emissions primarily stem from the combustion of fossil fuels and the manufacturing of cement. Various fossil fuels release different quantities of carbon dioxide per unit of energy use; for instance, oil emits approximately 50 percent more carbon dioxide than natural gas, while coal releases roughly twice as much. Cement manufacturing contributes about half a metric ton of carbon dioxide for each metric ton of cement produced. Data on carbon dioxide emissions encompass gases emitted from fossil fuel combustion and cement production but exclude emissions related to land use changes such as deforestation. This metric is measured in metric tons per capita. Source: World Data Bank.

Population-weighted exposure to ambient PM2.5 pollutions ($PM_{2.5}$**)** represents the average level of exposure for a nation's population to concentrations of suspended particles with aerodynamic diameters less than 2.5 microns. These fine particles can penetrate deep into the respiratory tract, leading to significant health risks. Exposure is computed by weighting the mean annual concentrations of PM2.5 based on the population in both urban and rural areas. This metric is measured in micrograms per cubic meter ($\mu g/m^3$) and refers to the mean annual exposure to PM2.5 air pollution. It indicates the population-weighted average concentration of suspended particles with an aerodynamic diameter of less than 2.5 micrometers in ambient air. Source: World Data Bank.

Nitrous oxide emissions (N_2O**)** refer to the release of nitrous oxide into the atmosphere, stemming primarily from agricultural biomass burning, industrial processes, and livestock management. The main sources include fossil fuel combustion, the use of fertilizers, rainforest fires, and animal waste. Nitrous oxide is a potent greenhouse gas characterized by its extended atmospheric lifetime, estimated at 114 years, in contrast to methane's 12-year lifespan. Notably, the global warming potential of nitrous oxide, expressed per kilogram, is approximately 310 times that of carbon dioxide within a 100-year timeframe. To facilitate comparison of the impact of various gases, emissions are quantified in metric tons per capita of CO_2 equivalent, employing the global warming potential metric. Source: World Data Bank.

Methane emissions (CH_4) refer to the release of methane into the atmosphere, originating primarily from human activities such as agriculture and industrial methane production. These emissions are quantified in metric tons per capita of carbon dioxide equivalents using the Global Warming Potential (GWP100) metric outlined in the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), with a GWP100 value of 21 for methane. This metric facilitates the comparison of the effective contributions of different gases. It is important to note that a kilogram of methane exhibits a heat-trapping capacity in the Earth's atmosphere that is 21 times greater than that of a kilogram of carbon dioxide within a 100-year timeframe. Source: World Data Bank.

Volatile organic compounds (VOCs) refers to a diverse group of organic chemicals that easily evaporate into the air at room temperature. Is considered to be the main precursors of photochemical air pollution. VOCs can originate from both natural and human-made sources, including industrial processes, vehicle emissions, solvents, and household products. Examples of VOC include benzene, formaldehyde, toluene, and acetone. Due to their ability to react with other pollutants in the presence of sunlight, VOC play a significant role in the formation of ground-level ozone and secondary organic aerosols, contributing to air pollution and its associated health and environmental impacts. This ozone can have a significant impact on human health by causing respiratory problems and respiratory diseases when found in excessive levels in the air. Data refer to VOC other than methane man-made emissions only and is measured in total emissions in kilograms per capita. Source: OECD Data.

Carbon monoxide (CO) is a colourless, odourless, and tasteless toxic gas that poses a significant risk to human health. It is produced by incomplete combustion of carbon-containing fuels such as wood, petrol, coal, natural gas, and kerosene, as well as through natural processes and biotransformation of halothanes within the human body. Despite being undetectable by human senses, CO can have severe health consequences, particularly due to its ability to form carboxyhemoglobin, reducing the blood's oxygen-carrying capacity. Exposure to elevated levels of CO can lead to various health effects, ranging from subtle symptoms to death. These emissions are measured in total kilograms per capita, excluding non-man-made emissions and international aviation and maritime transport emissions. Source: OECD Data.

Nitrogen oxides (NO) is a colorless and odorless chemical compound formed during combustion at high temperatures in the presence of air, such as in internal combustion engines of vehicles and industrial processes. It is an atmospheric pollutant that contributes to the formation of tropospheric ozone and smog. NO can also react with other compounds in the atmosphere to form nitrogen dioxide (NO2), another common atmospheric pollutant. Nitrogen monoxide can have adverse effects on human health, including respiratory irritation and difficulty breathing, especially in individuals with preexisting respiratory conditions. They are of concern because of their negative effects both on human health and on the environment. The data refer only to man-made emissions and are measured in total kilograms per capita. Source: OECD Data.

Appendix III

This appendix contains the descriptive analysis of some indicators of environmental degradation used in Chapter II.

In Table A.1., which is available on the following page, we can observe how throughout the period (1990-2019), most countries managed to reduce their emissions of nitrous oxide (N_2O), with the exception of Korea (0.4%). Before 2008 and after 2008, a slowdown in the reduction of N_2O emissions is observed, although at a lower level, like the Czech Republic (0.5% after 2008, compared to -2.7% before) and Hungary (changing from -2.7% to 0.3%). While countries like Korea maintain positive rates in emissions after 2008 (0.8% after 2008, compared to 0.1% before).

For methane (CH_4) emissions, we find diverse trends in the data. Some countries, like the United Kingdom (-3.2%), the Netherlands (-2.6%), Sweden (-2.6%) and Germany (-2.6%), show a constant decrease during the whole period. Meanwhile, other countries show no significant changes, like Portugal (0.0%). Before the GR, most countries exhibited a negative trend in CH_4 emissions, indicating a reduction. However, after the GR, changes in trends are observed, for example countries like the United States, shifting from -1.3% before the GR to a positive growth rates after (1.0%). Other countries, like the Czech Republic, experienced a slowdown in the decrease of emissions (-2.9% to -1.3%). In contrast, other countries like Iceland maintained a downward trend, but at a faster rate (-0.3% to -2.4%).

In relation to the evolution of Volatile Organic Compounds (VOCs) most countries show negative emission rates indicating a decrease in emissions over time. Some countries show more pronounced decreases in VOCs emission rates, such as Switzerland (-5.4%) and the United Kingdom (-4.8%), signalling a significant reduction in emissions during this period. Before 2008, in general, most countries show negative rates of VOCs emission, and after 2008 they show a decrease in the speed of emissions reduction of VOCs. For example, Germany (-2.3% after 2008, compared to -5.9% before) and the Netherlands (-1.5% after 2008, compared to -5% before).

We also observed a reduction in the evolution of carbon monoxide (CO) emissions. From 1990 to 2019, the leaders in reduction were the United Kingdom, with a decrease of 6.7%, followed by Ireland, with an impressive -6.2%. Before 2008, in general, countries stood out with more pronounced decreases, such as Germany (-7.0%) and the United Kingdom (-6.8%). However, there were some countries that exhibited less negative or even positive rates before 2008, like Iceland (1.8%) and Poland (-0.8%). After 2008, the countries showed a decrease in the speed of CO emissions reduction, like Germany (-2.9% after 2008, compared to -7.0% before) and Japan (-2.7% to 1.4%).

For nitrogen oxides (NO) emissions we observe variations in the magnitude. The United Kingdom and the Czech Republic emerged as frontrunners in reduction, showcasing a significant decrease of -5.1% each. Meanwhile, Australia showed a positive rate of 0.4%. Before 2008, in general, most countries exhibited negative rates of NO emission. But after 2008, some countries showed a decrease in the speed of NO emissions reduction. For example, the Czech Republic went from a reduction of -5.5% to -4.3%, and Germany decreased from -3.6% to -3%. However, it is Greece and the United States that stand out for demonstrating significant efforts in emission reduction. Greece shifted from an increase of 0.1% to a reduction of -5.1%, while the United States transitioned from a -3% to a -7.1% reduction.

Table A.1. Descriptive analysis

	N_2O			CH_4			VOCs			CO			NO		
	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19	90-19	90-08	08-19
Australia	-2.2	-2.5	-1.7	-1.7	-2.0	-1.2	-2.2	-2.5	-1.8	-4.3	-4.3	-4.2	0.4	0.6	0.1
Austria	-1.4	-1.6	-0.9	-2.3	-2.4	-2.2	-4.3	-4.8	-3.5	-3.6	-4.6	-2.0	-1.9	-0.5	-4.2
Belgium	-2.5	-2.6	-2.2	-2.2	-2.3	-2.0	-4.2	-4.7	-3.4	-5.2	-5.2	-5.2	-3.8	-2.7	-5.7
Canada	-0.9	-1.0	-0.8	0.3	0.4	0.2	-2.3	-1.7	-3.2	-4.3	-4.4	-4.0	-2.6	-1.6	-4.1
Czech Republic	-1.5	-2.7	0.5	-2.3	-2.9	-1.3	-3.5	-4.1	-2.5	-3.4	-4.6	-1.2	-5.1	-5.5	-4.3
Denmark	-1.6	-2.1	-0.9	-1.1	-0.5	-2.0	-2.9	-2.5	-3.5	-4.6	-3.6	-6.3	-4.2	-3.4	-5.5
Finland	-1.2	-0.2	-2.9	-2.4	-2.6	-2.2	-3.8	-3.9	-3.6	-2.9	-3.1	-2.7	-3.6	-2.9	-4.9
France	-2.1	-2.6	-1.2	-1.1	-0.7	-1.8	-3.8	-4.3	-3.1	-5.1	-5.1	-5.0	-3.8	-3.3	-4.6
Germany	-2.4	-2.3	-2.5	-2.6	-2.9	-2.1	-4.6	-5.9	-2.3	-5.4	-7.0	-2.9	-3.4	-3.6	-3.0
Greece	-2.0	-2.2	-1.9	-0.7	-0.4	-1.2	-2.8	-1.5	-4.8	-3.5	-3.2	-4.1	-1.9	0.1	-5.1
Hungary	-1.6	-2.7	0.3	-1.5	-1.9	-1.0	-3.1	-4.3	-1.1	-4.5	-5.5	-2.8	-2.4	-2.1	-2.8
Iceland	-1.3	-1.1	-1.7	-1.1	-0.3	-2.4	-3.0	-3.3	-2.7	0.6	1.8	-1.3	-2.6	-1.8	-3.9
Ireland	-1.4	-1.9	-0.8	-1.2	-1.4	-0.7	-2.1	-2.8	-1.0	-6.2	-5.8	-6.8	-2.8	-2.0	-4.2
Italy	-2.0	-2.1	-1.9	-0.5	-0.1	-1.1	-2.8	-2.7	-3.1	-4.2	-3.9	-4.7	-4.1	-4.1	-4.3
Japan	-1.4	-1.8	-0.8	-1.2	-1.2	-1.1	-3.1	-3.6	-2.4	-1.2	-2.7	1.4	-1.9	-1.1	-3.1
Korea	0.4	0.1	0.8	-0.9	-0.9	-0.9	-	-	-	-	-	-	-	-	-
Netherlands	-2.8	-3.8	-1.0	-2.6	-3.2	-2.0	-3.7	-5.0	-1.5	-3.3	-3.1	-3.7	-4.2	-3.4	-5.4
Norway	-2.1	-1.9	-2.5	-1.6	-1.2	-2.2	-3.7	-3.9	-3.3	-3.1	-3.2	-3.0	-1.6	-0.4	-3.5
Poland	-0.4	-0.1	-0.9	-1.5	-1.8	-1.1	-0.5	0.1	-1.5	-1.1	-0.8	-1.4	-2.0	-1.6	-2.5
Portugal	-1.1	-0.8	-1.7	0.0	0.1	-0.3	-2.1	-2.6	-1.2	-3.7	-4.0	-3.4	-1.9	-0.9	-3.6
Spain	-1.0	-1.3	-0.5	-0.2	-0.3	0.0	-2.8	-3.5	-1.6	-4.0	-5.3	-1.8	-2.9	-1.9	-4.6
Sweden	-0.9	-1.0	-0.7	-2.6	-2.3	-3.2	-3.9	-3.8	-4.0	-5.0	-5.4	-4.2	-3.5	-3.1	-4.1
Switzerland	-1.4	-1.2	-1.6	-1.7	-1.5	-2.0	-5.4	-6.3	-4.0	-6.1	-6.5	-5.4	-3.8	-3.3	-4.8
United Kingdom	-3.0	-3.9	-1.4	-3.2	-2.7	-4.0	-4.8	-5.9	-3.0	-6.7	-6.8	-6.5	-5.1	-4.4	-6.3
United States	-0.6	-0.8	-0.3	-0.5	-1.3	1.0	-3.2	-3.7	-2.3	-4.8	-5.3	-3.9	-4.6	-3.0	-7.1

The table presents the growth of the variables (in %) for the periods 1990-2019, 1990-2008 and 2008-2019.

Appendix IV

This appendix contains the classification of the macroeconomic variables, used in chapter 3, according to their area of origin.

Table A1: Business cycle variables. tcode indicates the transformation we have made to make the series stationary:

(1) No transformation, (2) Δx_t, (3) $\log(x_t)$, (4) $\Delta\log(x_t)$

Id	Description	tcode
var1	Gross Domestic Product-Constant Prices 2015	4
var2	GDP per capita-Constant Prices 2015	4
var3	Final consumption expenditure of households and NPISHs-Constant Prices 2015	4
var4	Final consumption expenditure of general government-Constant Prices 2015	4
var5	GVApb Agriculture, forestry and fishing-Constant Prices 2015	4
var6	GVApb Industry. Energy industry-Constant Prices 2015	4
var7	GVApb Industry. Manufacturing industry-Constant Prices 2015	4
var8	GVApb Construction-Constant Prices 2015	4
var9	GVApb Services-Constant Prices 2015	4
var10	GVApb Services. Public administration, education and health-Constant Prices 2015	4
var11	Exports of goods-Constant Prices 2015	4
var12	Exports of services-Constant Prices 2015	4
var13	Imports of goods-Constant Prices 2015	4
var14	Imports of Services-Constant Prices 2015	4
var15	Gross Fixed Capital Formation	4
var16	GFCF. Tangible fixed assets. Construction. Dwellings	4
var17	GFCF. Tangible fixed assets. Machinery, equipment and weapon systems.	4
var18	GFCF. Tangible fixed assets. Cultivated biological resources	4
var19	GFCF. Intangible fixed assets. Intellectual property products	4
var20	Degree of Utilisation of Productive Capacity	2
var21	Net Property Income	4
var22	Net current transfers	2
var23	Adjustment for change in net equity of households in pension funds reserves	2

var24	Households' saving	4
var25	Household saving rate	2
var26	Households and NPISHs Final consumption expenditure per capita-Constant Prices 2015	4
var27	Consumption of fixed capital	4
var28	Net national disposable income	4
var29	National balance of government consumption expenditure	4
var30	National net lending or net borrowing	2
var31	Non-financial resources of general government (NFR/GNI)	4
var32	General government property income	4
var33	Current taxes on income, wealth, etc.	4
var34	Social contribution	4
var35	General government capital resources	4
var36	Social benefits. Social transfers in kind and others (output purchased on the market)	4
var37	Operating subsidies (subsidies on products and others)	3
var38	General government debt (Excessive Deficit Procedure)	4
var39	Government expenditure on education, total (% of GDP)	2
var40	Industrial production index - Consumer goods	2
var41	Industrial production index - Consumer durables	2
var42	Industrial production index - non-durable consumer goods	2
var43	Industrial Production Index - Capital goods	2
var44	Industrial Production Index - Intermediate goods	2
var45	Industrial Production Index - Energy	2
var46	Adjusted savings: carbon dioxide damage (% of GNI)	2
var47	Adjusted savings: consumption of fixed capital (% of GNI)	2
var48	Adjusted savings: education expenditure (% of GNI)	2
var49	Adjusted savings: gross savings (% of GNI)	2
var50	Adjusted savings: natural resources depletion (% of GNI)	2
var51	Adjusted savings: net national savings (% of GNI)	2
var52	Adjusted savings: particulate emission damage (% of GNI)	2
var53	Consumer price index (2010 = 100)	2

Table A2: Labor market variables. tcode indicates the transformation we have made to make the series stationary:

(1) No transformation, (2) Δx_t, (3) $\log(x_t)$, (4) $\Delta\log(x_t)$

Id	Description	tcode
var54	Active population	4
var55	Unemployed total	4
var56	Employed total	4
var57	Salaried employees total	4
var58	Full time equivalent jobs in employed employment	4
var59	Full time equivalent jobs in Salaried employees' employment	4
var60	Thousands of hours worked - Employed	4
var61	Thousands of hours worked - Salaried employees	4
var62	Unemployed excl. long-term unemployed	4
var63	Long-term unemployed	4
var64	Unemployment rate of unemployed excluding the long-term unemployed	2
var65	Unemployment rate of long-term unemployed	2
var66	Employed in agriculture, livestock, forestry and fishing	4
var67	Employed in industry	4
var68	Employed in the energy industry	4
var69	Employed in manufacturing industry	4
var70	Employed in construction	4
var71	Employed in services for sale	4
var72	Employed in services not intended for sale. Public administration, education and health	4
var73	Salaried employees in agriculture, livestock, forestry and fishing	3
var74	Salaried employees in industry	4
var75	Salaried employees in energy industry	4
var76	Salaried employees in manufacturing industry (Wage and salary earners)	4
var77	Salaried employees in construction (Wage and salary earners)	4
var78	Salaried employees in services for sale (Wage and salary earners)	4
var79	Salaried employees in non-sales services (Public administration, education and health)	4
var80	Average wage (Renumbering of employees / Wage earners)	4
var81	Average wage in agriculture, livestock, forestry and fishing	4

var82	Average wage in industry	4
var83	Average wage in energy industry	4
var84	Average wage in manufacturing industry	4
var85	Average wage in construction	4
var86	Average wage in services for sale	4
var87	Average wage in non-sales services. Public administration, education and health	4
var88	Registered Unemployment	4
var89	Unemployed persons receiving unemployment benefits	4
var90	Unit Labour Cost	1
var91	Unit Labour Cost in the Agriculture, Livestock and Fisheries Sector	2
var92	Unit Labour Cost in the Energy Sector	2
var93	Unit labour cost in the Construction Sector	2
var94	Unit labour cost in Services for Sale	2
var95	Unit labour cost in Non-Sale Services	2
var96	Activity rate	2
var97	Occupation rate	2
var98	Unemployment rate	2

Table A3: Demographic variables. tcode indicates the transformation we have made to make the series stationary:

(1) No transformation, (2) Δx_t, (3) $\log(x_t)$, (4)$\Delta \log(x_t)$

Id	**Description**	**tcode**
var99	Age dependency ratio, old (% of working-age population)	2
var100	Age dependency ratio, young (% of working-age population)	2
var101	Female population (Thousands of persons)	4
var102	Male population (Thousands of persons)	4
var103	Total population	4
var104	Refugee population	4
var105	Rural population (% of total population)	2
var106	Urban population (% of total population)	2
var107	Population in urban agglomerations of more than 1 million (% of total population)	2

var108	Gender Development Index	2
var109	Gender Inequality Index	2
var110	Gini index	2
var111	Net migration (Per 1,000 inhabitants)	2
var112	Primary education, pupils	4
var113	Secondary education, pupils	4
var114	Average age at childbearing (years)	4
var115	Adolescent Birth Rate (births per 1,000 women ages 15-19)	2
var116	Crude birth rate (births per 1,000 inhabitants)	2

Table A4: Health system-related variables. tcode indicates the transformation we have made to make the series stationary:

(1) No transformation, (2) Δx_t, (3) $\log(x_t)$, (4) $\Delta\log(x_t)$

Id	**Description**	**tcode**
var117	Current health expenditure, total (Per capita, constant 2015, PPP)	4
var118	Current health expenditure, government schemes (Per capita, constant 2015, PPP)	4
var119	Current health expenditure, voluntary/out-of-pocket (Per capita, constant 2015, PPP)	4
var120	Inpatient curative and rehabilitative care expenditure (Per capita, constant 2015, PPP)	4
var121	Medical technology patents (Triadic, Inventor's country, Priority date)	4
var122	Human Development Index	2
var123	Incidence of HIV, ages 15-49 (per 1,000 uninfected population ages 15-49)	2
var124	Acquired immunodeficiency syndrome incidence (Per 100,000 population)	2
var125	Immunisation: Diphtheria, Tetanus, Pertussis (% of children immunised)	2
var126	Immunisation: Measles (% of children immunised)	2
var127	Injuries in road traffic accidents (Injured per million population)	2
var128	Hospital aggregates: Curative care average length of stay (Days)	4
var129	Hospital aggregates: Inpatient care average length of stay (all hospitals) (Days)	4
var130	General hospitals (Per million population)	2
var131	Beds in publicly owned hospitals (Per 1,000 population)	2
var132	Nurses and midwives (per 1,000 people)	2
var133	Pharmacists licensed to practice (Density per 1,000 population (head counts))	2
var134	Physicians (per 1,000 people)	2

var135	Alcohol consumption (Litres per capita (15+))	3
var136	Tobacco consumption (% of population aged 15+ who are daily smokers)	2
var137	Fruits supply (Kilos per capita per year)	4
var138	Sugar supply (Kilos per capita per year)	4
var139	Total calories supply (Kilocalories per capita per day)	4
var140	Total fat supply (Grams per capita per day)	4
var141	Total protein supply (Grams per capita per day)	4
var142	Vegetables supply (Kilos per capita per year)	3

Table A5: Environmental variables. tcode indicates the transformation we have made to make the series stationary:

(1) No transformation, (2) Δx_t, (3) $\log(x_t)$, (4)$\Delta\log(x_t)$

Id	**Description**	**tcode**
var143	Material footprint per capita (tonnes)	4
var144	Greenhouse gas emissions total (kt of CO_2 equivalent)	4
var145	Hydrofluorocarbons (HFCs) emissions (Tonnes of CO_2 equivalent, Thousands)	4
var146	Perfluorocarbons (PFCs) emissions (Tonnes of CO_2 equivalent, Thousands)	4
var147	Carbon Dioxide emissions (CO_2) (Tonnes of CO_2 equivalent, Thousands)	4
var148	Methane (CH_4) emissions (Tonnes of CO_2 equivalent, Thousands)	4
var149	Nitrous oxide (N_2O) emissions (Tonnes of CO_2 equivalent, Thousands)	4
var150	Sulphur hexafluoride (SF_6) emissions (Tonnes of CO_2 equivalent, Thousands)	4
var151	Carbon Monoxide emissions per capita (CO) (Kilograms per capita)	4
var152	Non-methane Volatile Organic Compounds emissions (VOCs) (Kilograms per capita)	4
var153	Nitrogen Oxides emissions per capita (NO) (Kilograms per capita)	4
var154	Sulphur Oxides emissions per capita (SO) (Kilograms per capita)	4
var155	$PM_{2.5}$ air pollution, mean annual exposure (micrograms per cubic meter)	4
var156	Percentage of population exposed to between 5 and 10 micrograms/m3	2
var157	Percentage of population exposed to less than 5 micrograms/m3	2
var158	Percentage of population exposed to more than 10 micrograms/m3	2
var159	Production-based CO_2 emissions (Tonnes, Millions)	4
var160	Total greenhouse gas emissions by Agriculture (Tonnes of CO_2 equivalent, Thousands)	4
var161	Total greenhouse gas emissions by Energy (Tonnes of CO_2 equivalent, Thousands)	4

var162	Total greenhouse gas emissions by gas (Tonnes of CO_2 equivalent, Thousands)	4
var163	Total greenhouse gas emissions by Industria (Tonnes of CO_2 equivalent, Thousands)	4
var164	Ammonia (NH_3) (Tonnes)	4
var165	Cement emissions in tCO_2/person	4
var166	Coal emissions in tCO_2/person	4
var167	Consumption emissions in tCO_2/person	4
var168	Oil emissions in tCO_2/person	4
var169	Transfer emissions in tCO_2/person	2
var170	Gas emissions in tCO_2/person	4
var171	Gas flaring emissions in tCO_2/person	4
var172	Total freshwater. Public water supply per capita	4
var173	Renewable internal freshwater resources per capita (cubic meters)	4
var174	Environmental Policy Stringency	2
var175	Environmentally related government R&D budget, % total government R&D	2
var176	Renewable energy consumption (% of total final energy consumption)	2
var177	Residential electricity price, USD per kWh (US Dollar, 2015)	4
var178	Forest area (% of land area)	2