Quantifying the Global and National Dynamics of Environmental Kuznets Curve using Chebyshev Distance in Feature Space

by

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A Dissertation Submitted to the
Graduate School of Sciences and Engineering
in Partial Fulfillment of the Requirements for
the Degree of

Master of Science

in

Data Science

August 11, 2022

Quantifying the Global and National Dynamics of Environmental Kuznets Curve using Chebyshev Distance in Feature Space

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I dedicate this thesis to Dr. Farzin Kamari who contributed beyond the boundaries of an advisor, like the closest friend.

ABSTRACT

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11th August 2022

There is an unresolved imbroglio regarding whether the global environmental issues are approaching the verge of irrecoverability, endangering the viability of living species and humanity. While the concept of the Environmental Kuznets Curve (EKC) is widely accepted in support for perpetual economic growth as the essential fuel for environmental sustainability, the contrasting evidence also designates industrialization and mass production as the principal cause of environmental deterioration. To date, despite its crucial significance in global policymaking, little has been done to quantify the dynamics of the EKC on a national and global level. Here, we introduce a quantification metric in a three-dimensional feature space of the available global panel data for annual CO_2 emissions per capita, Gross Domestic Product (GDP) per capita and year. We propose the Chebyshev distance between the data points and the vertices of the cubic feature space as a metric for the national and global EKC. Based on our proposed methodology, we classify thirty countries with the greatest global cumulative CO_2 emissions in five categories and further explain the dynamics of EKC in each category. Our results demonstrate that France, Germany, and the United Kingdom are aligned with the EKC hypothesis, but other countries are more consistent with non-EKC scenarios. We also show how Poland and Mexico have gone through constant economic growth without additional CO_2 emissions. Lastly, we discuss the relative performance of countries on a global level according to our methodology and propose directions for future research.

ÖZETÇE

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Bilgisayar Bilimleri ve Mühendisliği, Yüksek Lisans

11 Ağustos 2022

Küresel çevre sorunlarının telafi edilemezliğin eşiğine yaklaşıp yaklaşmadığı, canlı türlerinin ve insanlığın yaşayabilirliğini tehlikeye atıp atmadığı konusunda çözülmemiş bir tartışma vardır. Çevresel Kuznets Eğrisi (EKC) kavramı, çevresel sürdürülebilirliğin temel yakıtı olarak sürekli ekonomik büyümeyi desteklemek için yaygın olarak kabul görürken, karşıt kanıtlar da sanayileşme ve seri üretimi çevresel bozulmanın başlıca nedeni olarak belirlemektedir. Bugüne kadar, küresel politika yapımındaki kritik önemine rağmen, EKC'nin dinamiklerini ulusal ve küresel düzeyde ölçmek için çok az şey yapılmıştır. Burada, kişi başına yıllık CO_2 emisyonları, kişi başına Gayri Safi Yurtiçi Hasıla (GSYH) ve yıl için mevcut küresel panel verilerinin üç boyutlu bir özellik uzayında bir ölçme metriği sunuyoruz. Veri noktaları ile kübik özellik uzayının köşeleri arasındaki Chebyshev mesafesini ulusal ve küresel EKC için bir metrik olarak öneriyoruz. Önerilen metodolojimize dayanarak, en büyük küresel kümülatif CO_2 emisyonuna sahip otuz ülkeyi beş kategoride sınıflandırıyor ve her kategorideki EKC dinamiklerini daha ayrıntılı olarak açıklıyoruz. Sonuçlarımız Fransa, Almanya ve Birleşik Krallık'ın EKC hipotezi ile uyumlu olduğunu, ancak diğer ülkelerin EKC dışı senaryolarla daha tutarlı olduğunu göstermektedir. Ayrıca Polonya ve Meksika'nın ek CO_2 emisyonları olmadan nasıl sürekli ekonomik büyüme kaydettiğini de gösteriyoruz. Son olarak, metodolojimize göre küresel düzeyde ülkelerin göreceli performansını tartışıyor ve gelecekteki araştırmalar için yönler öneriyoruz.

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ABBREVIATIONS

BOD	Biological Oxidant Demand
C	Celsius
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxidant Demand
EKC	Environmental Kuznets Curve
F	Fahrenheit
GDP	Gross Domestic Product
GED	Global Environmental Degradation
GEMS	Global Environmental Monitoring System
GMSL	Global Mean Sea Level
NAFTA	North American Free Trade Agreement
NBER	National Bureau of Economic Research
NO_x	Nitrogen Oxides
OECD	Organization for Economic Co-operation and Development
ORNL	Oak Ridge National Laboratory
R&D	Research and Development
SO_2	Sulphur Dioxide
US	United States

Chapter 1:
INTRODUCTION

1.1 Preface

The global community has been experiencing a permanent upward trend in CO_2 emission statistics from the industrialization era [1]. Although a slightly downward trend can exist in limited periods such as the recent COVID-19 pandemic or the financial crisis of 2009, the overall trend continually increases at an even higher rate [2][3]. The obvious outcome of such a perpetual increase may lead to climate change in different shapes. The greenhouse effect, global warming, desertification, deforestation, and loss of biodiversity are only some disastrous terminologies from a long list of environmental concerns for humankind [4]. Evidence has shown that these events can deteriorate the public health and the quality of life in societies [5]. However, despite the pessimism during the recent decades, sceptics of global warming believe that there exists a ‘hype’ in the scientific literature and that the situation will totally be under control. Skeptics further believe in the case that the pattern of emissions is not ever-increasing in the future, and that the severity of the problem will not threaten the living organisms on a global scale [6]. Nonetheless, researchers and experts are always concerned to touch an irreversible stage, in which the sustainability of societies and humankind will be seriously threatened, and there will be no time for an effective action. They emphasize that changes occur gradually and consistently; so if the current trend do not change, the tangible adverse outcomes would be the case soon [7]. Hence, they emphasize unified cooperated action to reverse the current trend. The concerned ones urge to find a way to change the focus of societies from sole economic growth to sustainability and environmental stability [8].

On the other hand, many argue that economic growth is compatible with environmental stability and even a prerequisite. They refer to Environmental Kuznets Curve (EKC) as their consideration point and discuss that economic growth finally will lead to environmental sustainability and less pollution creation [9]. Nevertheless, a great debate exists, and both sides support their belief by different case studies. The argument for CO_2

emission -the main contributor to global climate problems- is more controversial and contradicting [10]. Altogether, it appears that the first step to preventing the current upward carbon emission trend (Fig. 1-1-1) and its consequent probable catastrophes should be reaching a consensus among pundits, which is more challenging than it sounds at first glance.

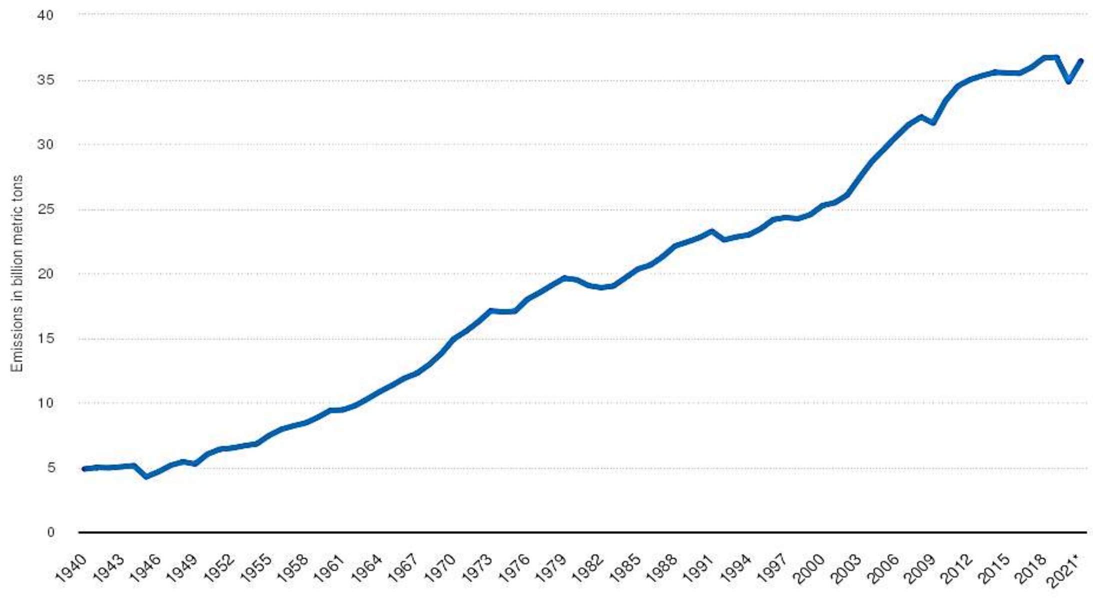

Figure 1-1-1. The annual CO2 emissions worldwide from 1940 to 2020.

1.2 Human Activities and Climate Change

While the terms climate change and global warming are often used interchangeably, global warming is only one facet of climate change. Climate change includes rising average temperatures, extreme weather events, shifting populations of animals and habitats, rising seas, and other impacts [11]. Scientists are always documenting and concerning the effects of these climate-related changes, which are mostly caused by global warming caused by humans. These catastrophes impose different costs on societies and not only will deteriorate the life quality of humankind but also even threaten the existence of humans [12].

By 2030, models predict global surface temperatures to be over 0.5°C (i.e. 0.9°F) warmer than the 1986-2005 averages[13], regardless of the pathway of carbon dioxide emissions that the planet follows. Several regional changes in climate are estimated to occur as a result of global warming, including increases in extreme temperatures across multiple regions [14]. Moreover, in 2020, the global mean sea level (GMSL) was the highest ever recorded. Based on tide gauge measurements, GMSL reconstructions suggest a rise of 21cm at an average rate of 1.7 mm/year from 1900 to 2020. The rate of GMSL growth accelerated to 3.3 mm/year from 1993 to 2018, and to 3.7 mm/year from 2006 to 2018, more than twice as quickly as in the previous century [15].

Humans are the primary reason for earth's rapidly changing climate. Increasing human activities have caused GHGs to rise consistently, pushing humankind very close to the dangerous levels of global warming predicted [16]. Since the expected catastrophe would be life-threatening for humankind in general terms, there would be some coordination events in the world community. For instance, at the 2015 Paris Climate Change Conference, almost every country committed to moving away from dirty fossil fuels toward cleaner, more intelligent energy options [8]. However, the total CO_2 emission trend would not be changed after this agreement. Although many countries formally committed themselves, nothing meaningful has been done in action [1].

Environmental experts refer to the industrial revolution as the split point from the long-run balanced path of growth and carbon emission. Since then, human activities have released vast amounts of carbon dioxide and other greenhouse gases into the atmosphere, ever-changing the earth's climate [17]. The mean temperature on the entire planet's surface has already increased by 1.1 centigrade degree due to CO_2 emissions from burning fossil fuels, such as coal. Although the essential contributors to global CO_2 emission are energy sources, the list is not limited to only these, and other pollutants have an also influential impact on the earth's total carbon emissions (Fig. 1-2-1) [1].

Climate change is a consequence of the biggest market failure that the world has ever seen [18]. The so-called greenhouse gas externalities are accompanied by a range of other market failures, including ones stemming from the absence of information on how emissions can be reduced, the net-of-effects phenomenon, and a lack of incentive for innovation. This institutional framework failure, in which these markets are operating, is a major design failure in the rules for the economy and production that enable, tolerate, or ignore these ecological impacts, and that allows corporations to ignore and fail to take responsibility for their damages [19]. The negative effects of greenhouse gases are thus outside of markets, meaning that businesses and consumers generally have an ethical--rather than economic--incentive to curb their emissions [20].

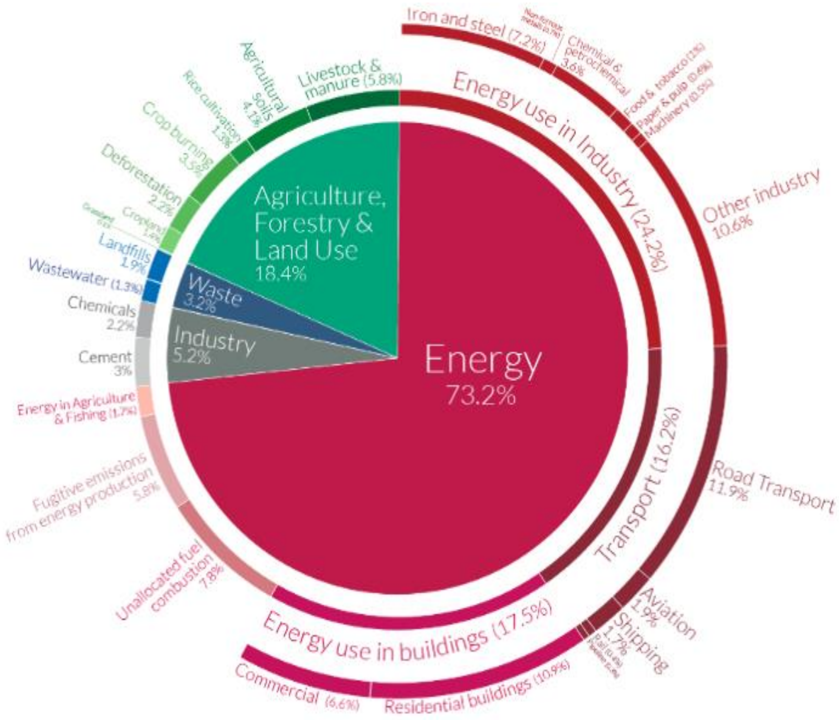

Figure 1-2-1. The greenhouse gas emissions by sector in year 2016

1.3 Different Shapes of Climate Change Costs

Urban areas are frequently located in dangerous places (such as along beaches), putting economic assets and individuals at increased risk from climate-related calamities [21]. To comprehend the ramifications of these hazards for cities, one should consider how they influence social and economic situations, as well as the foundations of urban function. Health consequences, food and water shortages, livelihood implications, and relocation are examples of social repercussions of climate change that directly affect citizens‘ physical and mental well-being [22]. Moreover, the uneven consequences of climate change on people, a phenomenon that has just lately entered the climate change discourse, are a significant component of the social dimension of climate change [23].

According to new research, climate change disproportionately affects individuals and groups with few resources or who are socially isolated. Economic repercussions, such as the demolition of a manufacturing base and the loss of commercial activity, interrupt the movement of products and services within a city, which finally limits the workforce's production ability. In other words, physical dangers are becoming more common and changing environmental circumstances interfere with the delivery of a wide range of services [23]. These conditions lead to restricting activities that make up a large part of the urban economy in certain circumstances. Climate changes in one location can affect the economics of cities all over the world due to globalization of business and trade, especially when transportation is hampered [24].

Although case studies often focus on specific economic or social impacts, research is increasingly emphasizing their interconnected nature. Climate-related economic losses diminish the resource's ability to solve social challenges. In other words, climate change-related events can put urban livelihoods at risk by impacting these resources. Simultaneously, some social and demographic factors, such as poverty, might make a city more vulnerable to the same disasters. Hence, climate change may worsen cities' current social and economic problems (e.g., rapid urbanization, poverty) from several interrelated channels [25].

It might be noteworthy to mention that global warming can also produce some local benefits, like fewer winter deaths in temperate climates and increased food production in certain areas. However, the overall effects of climate change are overwhelmingly and incomparably adverse in a way the focus of the current literature is to how decrease expected negative outcomes [26].

1.4 Growth Debate

Growth debates have been controversial topics among economists for a long time. There would be two central contrary beliefs: if growth and environmental preservation are compatible, or if focusing on economic growth would sacrifice environmental sustainability [27]. The proponents of economic growth and environmental protection compatibility refer to empirical cases where environmental indices are improving in developed countries. In contrast, the others emphasize the long-run trends and disagreeing empirical studies [28].

It might be sensible to assume that increased output will inevitably result in increased environmental deterioration [29]. Higher-income levels, on the other hand, may lessen environmental deterioration, making economic development a necessary prerequisite for environmental betterment. If this is the case, development may be viewed as a great tool for poor countries to enhance environmental quality [30]. However, the claim that economic growth is ultimately environmentally friendly is contentious since it leads to the concept of a development path, a stage-based relationship between environmental quality and economic growth [31].

Indeed, over time, people's perspectives on the link between economic growth and environmental quality have grown and altered. Before 1970, it was thought that raw material, energy, and natural resource consumption grew at a nearly constant pace (known as a steady-state condition) as the economy grew. Many ecological economists raised worries about the supply of natural resources on the planet in the early 1970s. They contended that the limited nature of environmental resources would stifle economic progress, and they advocated for a steady-state economy with zero growth to avert future ecological disasters [32]. However, both theoretically and empirically, this point of view has been questioned. Empirical studies reveal that the consumption ratio of various metals to income in industrialized nations fell throughout the 1970s, contradicting the constraints to the growth view‘s expectations [33]. This viewpoint prompted researchers to investigate the association between metal consumption intensity and income, and they discovered an Inverted-U curve. This inverted-U curve, also known as the intensity-of-use theory, shows that beyond a certain amount of money, the intensity of material usage declines [34].

Empirical data on numerous contaminants has been accessible since the beginning of the 1990s through the Global Environmental Monitoring System (GEMS), the OECD's environmental data compendium, the CO_2 emission predictions from the Oak Ridge

National Laboratory (ORNL), and other sources. Because of these data resources, some writers have decided to investigate the inverted-U curve theory regarding income and environmental quality variables. The first empirical investigation, by 'Grossman and Krueger (1991)' in the working paper is followed by several of the others [35].

1.5 Environmental Kuznets Curve (EKC)

1.5.1 EKC Emergence

The inverted-U, or Kuznets curve, was coined by Simon Kuznets to characterize the relationship between per capita income and income inequality (for which he received a 1971 Nobel Prize) [36]. According to Simon Kuznets, income inequality rises in conjunction with economic development, stabilizes at a certain point, and then drops, implying a U-shaped connection between the two variables. To put it another way, Kuznets predicted that as per capita income rises, income disparity rises as well, before dropping beyond a tipping point. In the early stages of economic growth, he represented uneven income distribution, which eventually advances towards more fairness as economic growth proceeds [37]. The Kuznets Curve is the traditional name for this observed empirical phenomenon.

The Kuznets Curve took on a new meaning in the 1990s and beyond. There is evidence that the amount of environmental degradation and per capita income have the same inverted-U-shaped connection as the original Kuznets Curve's income disparity and per capita income. The Kuznets Curve in new context is used to describe the link between measured environmental quality (for example, SO_2 concentration) and per capita income. Hence, the 'Environmental Kuznets Curve', or 'EKC', was defined as an inverted-U-shaped relation between economic growth and recorded pollution indicators (environmental quality) [35].

The first series of empirical EKC research emerged in a variety of working studies: an NBER research report as part of the research on the environmental effects of NAFTA[35], the World Bank's 1992 World Development Report [38], and a Development Debate paper as part of research for the International Labor Organization [39]. Grossman and

Krueger originally identified an inverted-U association between pollutants (SO_2 and smoking) and per capita income in an NBER working paper, which was eventually published in 1993 [35]. Due to its similarities to Kuznets' inverted-U relation between income inequality and economic development, the inverted-U relationship between pollution and economic development was given Kuznets' name later on. The term 'Environmental Kuznets Curve' or 'EKC' was initially proposed by Panayotou (1993) [39].

Environmental awareness is limited, or nonexistent, and environmentally friendly technology is not available, which corresponds to the early stages of economic development. Environmental deterioration rises in tandem with rising income until a point is reached beyond which, as per capita income rises, environmental quality improves. This connection can be shown using an inverted-U-shaped curve. Following Kuznets' observation, it is referred to as the EKC [40]. This EKC hypothesis aims to reflect a long-term link between environmental effects and economic growth. At the take-off stage, the pace of depletion of resources begins to surpass the rate of resource renewal, and waste creation grows in quantity and toxicity as economic growth accelerates with intensive farming and other resource exploitation. At higher levels of development, a transition toward information-intensive industries and services, combined with the increasing environmental consciousness, implementation of environmental laws, improved technology, and higher environmental expenses, results in environmental degradation leveling off and gradually declining [41]. It is believed that after income has surpassed the EKC turning threshold, the shift to enhancing environmental quality will begin. As a result, it might represent the natural progression of economic growth from a clean agricultural economy to a polluting industrial economy, and then to a clean service economy [42].

1.5.2 Proposed Reasons for the EKC Existence

There are several reasons proposed for the EKC hypothesis justification. Below the most valid ones would be introduced.

People care more about the health of the environment they are living in as their money rises, and this desire for a better environment leads to fundamental changes in the economy that lessen environmental deterioration. The importance of income elasticity in environmental quality demand has been stressed in most EKC models. This elasticity is frequently cited as the primary factor for lower emission levels [43].

Economic expansion has a scale effect that is harmful to the environment. According to the EKC, the scale effect has a detrimental influence in the early phases of expansion, but this is later overcome by the beneficial impact of technology and composition impacts. As income rises, the economy's structure tends to shift, resulting in a progressive growth in cleaner, less polluting activity. Furthermore, because a wealthy country can afford to invest more in R&D, technical development happens as a result of economic expansion, and old, filthy industries are replaced with new, cleaner technology [44].

One of the topics that may have ambiguous consequences on environmental indexes and EKC literature is international trade. On the one hand, as it increases the volume of economic activity, it can have a detrimental impact on environmental problems. However, it increases manufacturing efficiency on a worldwide scale, which can reduce the amount of pollution produced. The overall impact of international trade is unclear because of these two opposing forces.[45].

With economic growth, economies advance with their social institutions that enforce environmental regulation. Developed countries are moving, now, from command-and-control policies to market-oriented forms of regulation. Environmental regulatory institutions are either weak or absent in less developed countries. In this situation, pollution can only be reduced if these poor countries focus on a few sources [46].

Because of the agricultural sector's relative importance, the early phases of expansion are frequently coupled with significant exploitation of natural resources. Over time, this tends to deplete the pool of natural capital. After a given point of development, efficiency in the use of natural resources improves when markets for environmental resources form and prices begin to reflect the worth of natural resources. The resulting rise in the price of natural resources decreases their use at later phases of development, as well as the related environmental damage. Furthermore, increased natural resource costs may help to expedite the transition to less resource-intensive technologies [47].

1.5.3 Empirical Studies

The inverted-U relation between income and urban and local air quality indices (SO_2: sulfur dioxide, suspended particle materials, CO: carbon monoxide, and NO_x: nitrous oxides, which directly influence human health) is typically evident. A set of studies accompanies this conclusion [48][49]. However, in general, there is no clear path of EKC for contaminants that have a little direct impact on health, but the enormous effect on climate change and long-run disasters in the literature. According to early and current research, global pollutants (like carbon dioxide emissions) increase or decrease monotonically as wealth rises, based on the different case studies [50]–[52].

The empirical evidence of EKC for indicators of water quality is considerably more ambiguous. Water quality is measured using three main categories of indicators: pathogen concentration in water (fecal and total coliforms), the amount of heavy metals (lead, cadmium, mercury, arsenic, and nickel) and toxic chemicals discharged in water by human activities, and measure of degradation of the water oxygen regime (dissolved oxygen, biological and chemical oxidant demand, i.e. BOD and COD). For various indicators, there is evidence of EKC, however numerous research come to differing conclusions concerning the form and peak of the curve. For several indicators, several authors find evidence of an N-shaped curve [52][53].

Moreover, to test the EKC hypothesis, other types of environmental indicators (municipal solid wastes, urban sanitation, and access to safe drinking water, energy consumption, and traffic volumes) are utilized. EKC is not supported by the majority of these indications [55]. Environmental issues that have a direct influence on human health (such as the provision of urban sanitation and clean water) tend to improve consistently with economic expansion, according to all studies. On the other hand, when environmental problems could be externalized (like in the case of municipal solid wastes), however, the curve does not decline even at high-income levels. In addition, in the case of deforestation, the evidence supporting EKC is debatable [55][56].

To conclude, the empirical studies illustrate various patterns of behavior for different indicators and case studies. However, contrary to this controversy in the literature, it is possible to categorize most case studies. For indicators that have a direct and tangible effect on the health quality of humans, two patterns are more common. The severity of environmental problems improves consistently with wealth increase, or it shows a U-inversed, EKC supporting pattern. However, the pattern for the indicators that do not have a direct impact on the human health quality and could be externalized is sophisticated and vague. Different patterns, such as consistent steady deterioration, N-shaped curve, or U-inverted cases, are repetitive in the literature [58]. Carbon dioxide is one of the pollutants that belong to this category, so it shows the complexity of finding a solution to harness its permanent growth and preventing global climate change [59].

1.6 EKC Methodology Drawbacks

It is apparent that EKC can take shape as a result of a variety of economic development variables. Because these components are interrelated, determining the factors that could dominate and regulate EKC design is challenging. As a result, sufficient attention must be paid to several factors that make up the economic–environmental system rather than focusing on a single dominating element. Reduced form models obstruct any understanding of the underlying dynamic of EKCs. Therefore, these analyses contains substantial flaws due to a lack of understanding of the interactions that characterize the behavior of environmental pressure. Understanding the downsides and devising methods to address them would be crucial to clarify the issue, allowing better policies to be implemented.

Lack of Prediction Ability

The goal of empirical research is not just to discover current relationships but also to aid in forecasting the future. The future prediction would be accurate only by considering all observed patterns and data. However, EKC assumes a sole path for growth-pollution relationship and ignores numerous cases in the history of developing countries and even developed ones. Developing countries show a completely different growth and pollution relationship pattern, which EKC cannot explain. Developing countries illustrate a different pattern because of negative growth rates and positive ones. As a result, they reach the same income with different pollution amounts during their history. In other words, EKC has an unwritten assumption in its examination that the countries always have positive growth rates, which is not the case in many instances. To sum up, the assumption of the united path of growth-pollution for all players provides nothing more for the prediction ability of future behaviors.

Oversimplification of the Future Behavior

According to the EKC theory, early surges in environmental pressure are temporary, while successive declines in environmental stress are permanent. Only a few researchers have questioned whether the observed decreases may be a one-time occurrence due to technical constraints. In this case, an 'N-shaped' curve would be the consequence. The challenge of keeping efficiency improvements (innovation) while continuing to boost production might explain a secondary increase in EKC. Hence, it might be an oversimplification to consider the decline of environmental pressure to continue forever. It would start rising or remaining stable through its evolution path. In other words, there should be specific criteria to determine if the EKC exists or not. Considering its existence only because of initial decline can be utterly misleading since it can again rise or be unchanged.

Blindness about Players' Interactions

Several important aspects, such as transboundary and intergenerational externalities, have been overlooked in the EKC research thus far. Since environmental disasters are stock variables, a local examination could be misleading without considering the role of interactions between different players on the global scale. Otherwise, the results could not be applicable to solve the global issues. One of the important things in this context is the role of trade. High-income countries have more options for reducing emissions since they can trade polluting sectors with other countries. Globalization has caused this opportunity for them to shift some industries to developing countries, so the pollution of the developed ones will decrease but at the expense of an increase in developing countries' pollution amount. Therefore, on a global scale, the result could be completely opposite of what is shown in the limited case studies. The EKC hypothesis is not capable to consider the interactions between players, so its results in the case studies are limited and cannot be applied on a global scale. In other words, it should be highlighted that, rather than country-specific pollution or emission levels, global environmental degradation (GED) levels owing to economic growth may be a key element (for global EKC), which has been overlooked in the existing EKC research.

Binary Structure: Absence of Numeric Index

The goal of the EKC hypothesis is only to examine the existence or non-existence of an inverted-U shape curve in the relationship between income and pollution. In other words, its format is binary and cannot describe the situation continuously throughout the time. This issue causes the policymakers cannot track the changes year by year. If one index could be in a numeric form, experts would examine the effects of different policies constantly. Although this issue is not directly the EKC problem, it shows a need for such an index for further and permanent analysis. The proposed numeric index should be able to track tiny modifications and degradation to establish if the trend is on the improvement path or not.

1.7 The Current Thesis

To find a sustainable solution to global environmental disasters, not confining all studies to the EKC hypothesis sounds necessary. The EKC's limitation discussed above restricts detailed examination from being deployed. Since the EKC method's drawbacks will prevent experts from finding a permanent global solution for the ongoing catastrophes, introducing a method and study based on that can address the EKC's flaws and give a more powerful tool to the researchers is essential. The new approach should be able to reduce the weaknesses of the traditional EKC analysis and provide an opportunity for accurate predictions as well as other mentioned shortcomings.

1.7.1 Aims and Objectives

The general goal of the current thesis is to investigate the extent of Environmental Kuznets Curve (EKC) implication on a national and global level. To approach our goal, our objective was to propose a novel computational methodology, i.e., (hyper)-cube modelling in Chebyshev space, to be able to quantify the dynamics of EKC on a national and global level. The following are the specific aims which are all satisfied in the subsequent sections:

i. Determining the conceptual and computational details of the hypercube modeling method in a 3-dimensional Chebyshev space
ii. Determining the Chebyshev distances between CO_2-GDP curve and the unit cube vertices considering national panel data per each country
iii. Determining the Chebyshev distances between CO_2-GDP curve and the unit cube vertices considering global panel data available
iv. Determining an index for the quantification of the extent of EKC

Chapter 2:
METHODS

2.1 *Preface*

The approach explanation begins with an illustration of a three-dimensional cube and can be further expanded for a more general topic in an n-dimensional hypercube. Each dimension in an n-dimensional hypercube space represents a feature we are interested in examining its relationship with the other dimensions (features). A unit cube would be used in three-dimensional space to examine three aspects and their interplay.

2.2 *Structure of Cubes*

As shown in Fig. 2-2-1, the axes of the cube are depicted based on the Z-up system. Concerning examining the Environmental Kuznets Curve's dynamic, it could be such an arrangement to depict Time on axis X, GDP per capita on axis Y, and Annual CO_2 Emissions per capita on axis Z.

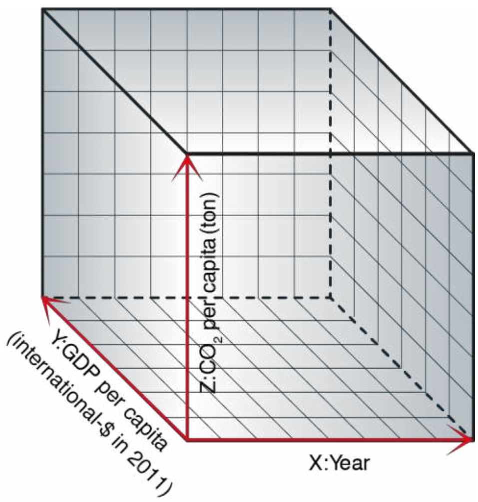

Figure 2-2-1. The primary depiction of the cube illustrating a three-dimensional feature space. As shown, the coordination system is z-up and axis units are enclosed in parentheses.

The crucial point about the structure of the cubes is that the length of all twelve segments is a unit. It means the starting point of each axis will be the lowest amount of data records, and the ending point of the segment will be indicated as the highest amount. For instance, in Fig. 2-2-2, the pollution-production relation is illustrated from 1900 to 1950, and from 1900 to 2000 for the country ‘A’. Although the amount of pollution and production in the year 1950 is the maximum limit in Fig. 2-2-2a and creates the cube’s vertex coordinates, they are inner points in Fig. 2-2-2b. It is because of the permanent growth of economic production and pollution from 1950 to 2000, which causes the edges to cover more domains in the fixed length of each edge. This property of the cube will assist us in assessing the countries’ (players) performances and their effects on the globe compared with each other. This trait will be discussed and explained in detail in the later sections.

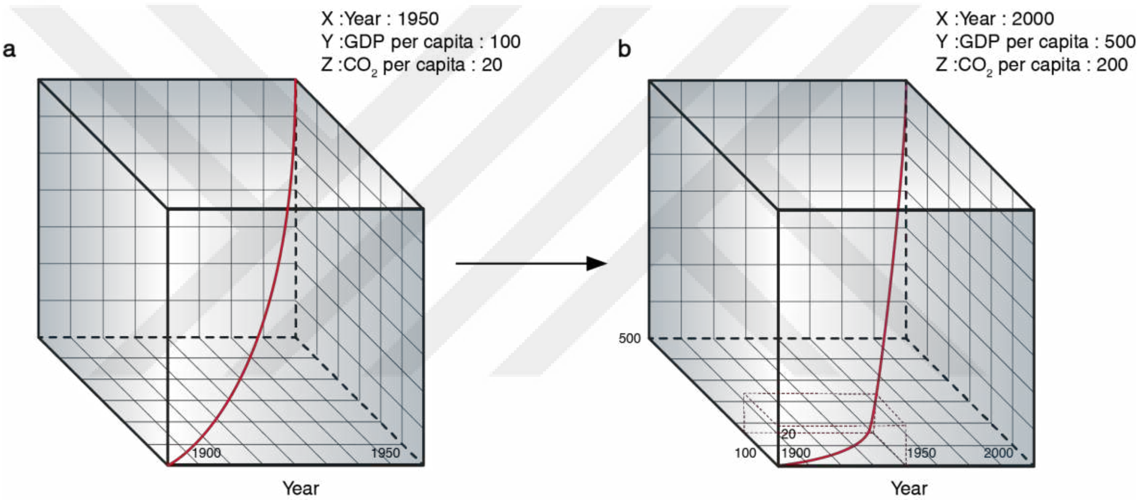

Figure 2-2-2. The axes of unit cube are updated based on the maximum of each feature.
(a) The trend between years 1900 to 1950 has been schematically illustrated. (b) the dashed red lines demonstrate the cube shown in panel a. The cube axes are updated based on the maximum of each feature.

Moreover, as shown in the Fig. 2-2-3, each axis would be normalized to the scale from zero to one. This normalization process would consider the lowest amount as zero and the highest amount as one and split the interval to their difference. For instance, if the historical data are available from 1800 until 2022, the time segment will start from 1800 and end in 2022, and the segment will be divided into 222 pieces. Hence, although the segment length would be unit and fixed, the scale of sub-fractions will be changed according to data divergence.

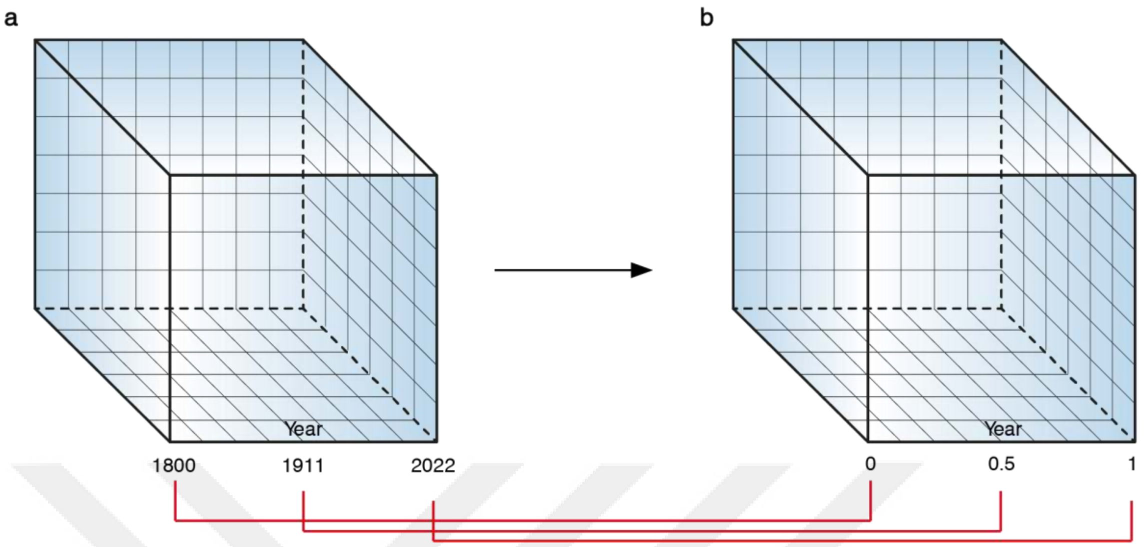

Figure 2-2-3. Min-max normalization of the feature space in unit cube.
(a) As an example, three time points in the year axis have been shown. (b) the same time points are shown after being min-max normalized. This normalization keeps the cube always unit.

2.3 Vertices Nomination Procedure

Since the vertices have a significantly noteworthy definition and application, the unique manner of the nomination for different vertices would make the following sections' explanations more straightforward. As mentioned, in a cube environment, Time would be depicted on axis X, GDP per capita on axis Y, and Emission per capita on axis Z. The nomination procedure of vertices is to call the starting point of each axis (segment) '0' and the ending point '1'. For example, vertex (XYZ: '0,0,0') will be defining a vertex where all three dimensions start from that point. Alternatively, vertex (XYZ: '1,0,1', X=1, Y=0, Z=1) shows a vertex that represents the ending points for Time and emission per capita and starting point for GDP per capita. In addition to being easily detected in a hypercube, this naming procedure has valuable features in the distance calculating concepts, which will be discussed and explained in other sections (Fig. 2-3-1).

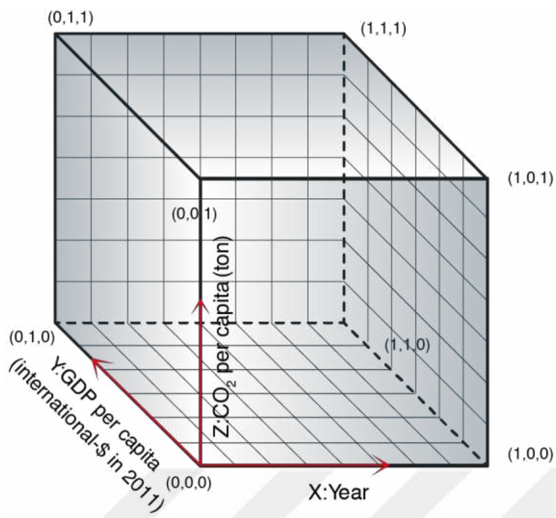

Figure 2-3-1. The nomenclature of the cube vertices with a binary approach.

2.4 *Interpretation of patterns in the Cube-based environment*

2.4.1 *Frequent Patterns: Clarifications and Properties*

It should be emphasized that the distribution of total change amount in comparison to other features determines how a feature would evolve. In other words, how three relative speed rates change – relative change rate of 'GDP and time', 'CO_2 emission and time', and 'GDP and CO_2 emission' - will specify how data points would be depicted in different phases. Since this concept could be a little challenging, first, the common patterns in a more sensible way are going to be discussed and in the next subsection, the general form of pattern recognition would be explained in detail.

Permanent growth of production and CO_2 emission

Wherein the given period, if there were permanent growth in production and CO_2 emission amounts, the path of the pollution-production relationship would start from the origin and finish in the vertex '1,1,1'.

If the CO_2 emission rise speed and production growth were constant, the evolution path would be a straight line that connects vertices '0,0,0' and '1,1,1'. In this case, all features grow with a uniform distribution. This constant relative change rate causes the data curve not to experience any curvature through its path from origin to the ‘1,1,1’ vertex (Fig. 2-4-1a).

If CO_2 emission growth was disproportionately more in the initial phase than production growth, but in the second half of the period, production grew faster than CO_2, a concave line will connect the two vertices. In other words, if the pollution pressure was severe in the initial phases and then relatively relieved – still increasing – the shape would be a concave line. This pattern might be seen in countries with historical huge polluting backgrounds for gaining limited growth (Fig. 2-4-1b).

Furthermore, assuming that the CO_2 emission pressure in the final stages would be more significant than in the initial stages compared to the production growth, the connecting line would be a convex one. This case can happen when there is a kind of sustainable growth in the initial stages, but in contrast, the country acts poorly environmentally in the final steps (Fig. 2-4-1c).

Historical massive growth-degradation

This type of pattern happens when the country experiences substantial economic growth and CO_2 emission in the initial phase. However, in the final phase, the economic growth and environmental degradation would be smoother compared to the past- still, economic growth and environmental degradation happen at a slower rate. In this case, emission and production correlate together perfectly (Fig. 2-4-1d).

Recent massive growth-degradation performance

This scenario is similar to the previous one, only with the difference that the player is inactive in production and pollution making in the initial stages. However, in the recent steps, it produces and pollutes more compared to its own past. Also, this pattern implies that growth and emission correlate well (Fig. 2-4-1e).

Equivalent to EKC

EKC equivalence in the 3D-cube-based environment and its properties might be considered the most critical pattern among others. EKC hypothesis brings up the idea that in the initial phases, the environmental degradation increases along with economic growth, but after a turning point, this trend would be ultimately vice versa meaning that the environmental indices like CO_2 emission will decrease although economic growth continues its progress. In other words, in the initial steps, production increases, and CO_2 emission correlates positively with it, but after the turning point, it correlates negatively to economic growth. As shown in the Fig. 2-4-1f, to illustrate its equivalent pattern in the cube environment, the data curve, after its initial start, will touch a point - maximum emission level - on the {‘001’, ‘011’, ‘101’, ‘111’} plane. Subsequently, it starts decreasing polluting and approaching to the vertex ‘110’. In the following sections, vertex ‘110’ would be nominated as the EKC vertex. The distance from it compared to other vertices would be an index in measuring the country’s performance compatibility with the EKC hypothesis (Fig. 2-4-1f).

Ultimate independence of growth and CO_2 emission

In the EKC hypothesis case, we assume that after the turning point, the evolution path will permanently continue toward environmental improvement or, in other words, towards the vertex ‘110’. However, it is not always the case, and it is communal to see that environmental degradation again starts increasing or being stable in a limited amount. As illustrated in Fig. 2-4-1g, the curve shows the scenario in which, after temporary enhancement, the index would not change with growth anymore. The more critical and typical case is when the environmental pressure again starts deteriorating by growth which is explained in the following pattern (Fig. 2-4-1g).

Temporary decrease of environmental degradation in the middle phase

Through the path of CO_2 emission – Production, it is feasible to observe that although environmental degradation increases by growth in the initial stages, a temporary environmental improvement occurs in the middle phases, and again the environmental situation starts deteriorating. In other words, during the middle interval of the examination period, CO_2 emissions decrease, but this improvement would not last, and the trend again increases. In this case, the curve looks like an 'N' shape with different possible curvatures (Fig. 2-4-1h).

In all previous pattern examples, there was positive economic growth throughout the period. However, in reality, most countries cannot gain continuous positive growth. Developing countries are constantly transitioning between positive and negative economic growth. This issue creates numerous patterns in which economic growth is not necessarily positive for the majority of the period. The following pattern instances will discuss the expected patterns with negative economic growth.

Negative economic growth with decreasing degradation

One of the common happenings in developing world history is that countries, after a period of economic growth with increasing environmental pressure, experience negative economic growth. This downturn in economic production usually corresponds with decreasing CO_2 emissions. If it were the case, the production-emission curve would approach the vertex '1,0,0' after reaching its largest production and pollution level, as shown in the Fig. 2-4-1i.

Negative economic growth with increasing degradation

In some cases, it could be observed that after an initial increase in production and CO_2 emission, the economic growth cannot continue and starts weakening. However, in this unexpected pattern, even when the economic growth is declining, CO_2 emission continues rising. Decreasing production along with increasing degradation means the data curve would progress toward the vertex '101'. This case sometimes can be observed in countries engaged in a war. Their economic growth is affected by war declines, but because of war-related emissions and, more importantly, changes in energy recourses to more polluting ones, their CO_2 emission intensifies.

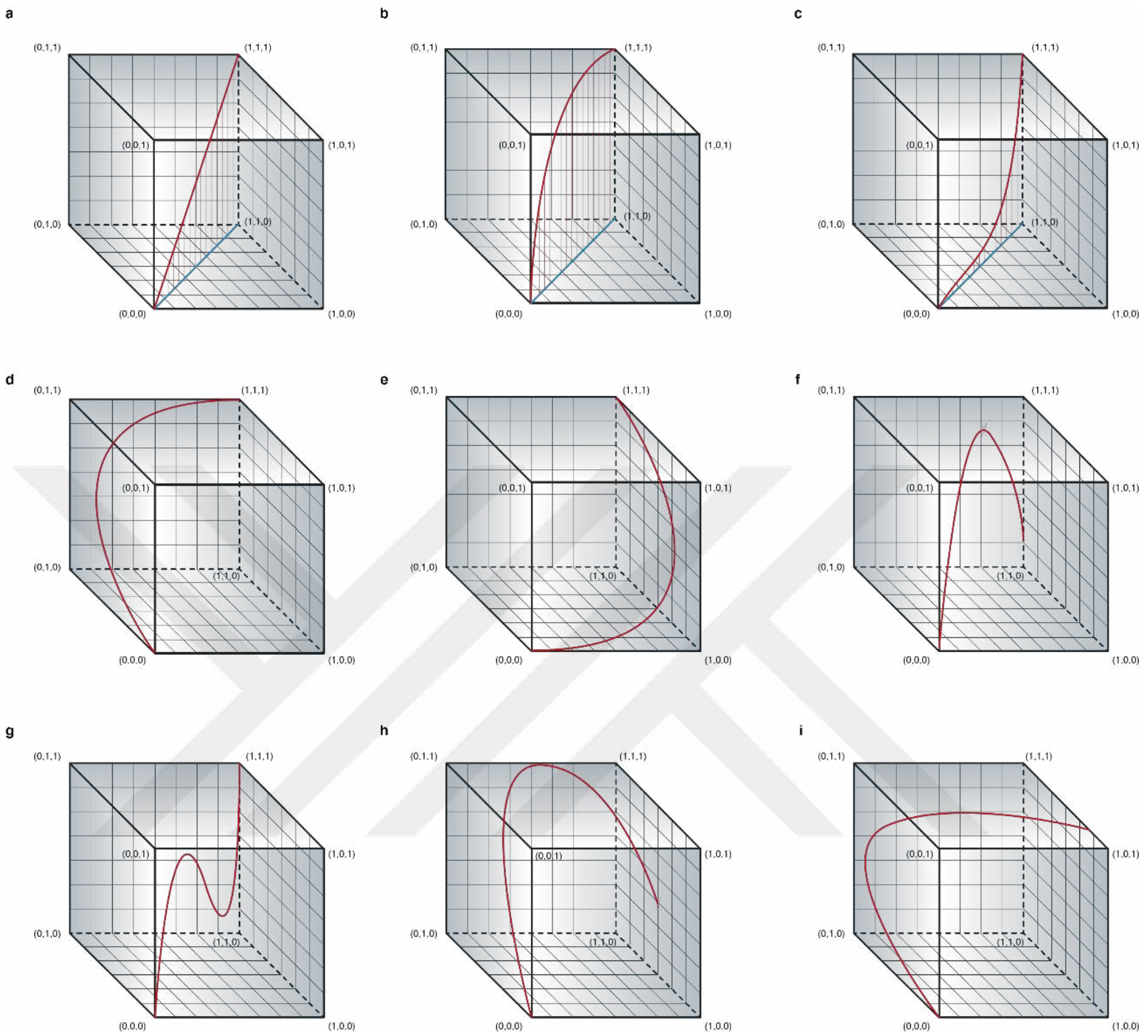

Figure 2-4-1. Possible scenarios in the schematic unit cube and the interpretation of the patterns. Please see the text for full explanations. (a) Permanent linear growth in GDP and CO_2 emission. (b) Permanent logarithmic growth in GDP and CO_2 emission. (c) Permanent exponential growth in GDP and CO_2 emission. (d) Historical massive growth-degradation. (e) Recent massive growth-degradation performance. (f) Equivalent to EKC. (g) Ultimate independence of growth and CO_2 emission. (h) Temporary decrease of environmental degradation in the middle phase. (i) Negative economic growth with decreasing degradation.

2.4.2 General tips for real cases interpretations

To explain patterns in a more general form, we will use the separating planes in the cube environment as hallmarks to show how a pattern should be interpreted. Hence, in this section, we will use the nomination of vertices to identify separating planes. These planes consist of two parallel cube edges and two diameters of parallel faces of the cube. Hence, the plane would be in a rectangle form, not a square.

By the way, it might be helpful to mention that this kind of general pattern recognition representation is based on the mathematical slope concept.

Plane {'000', '001', '111', '110'} as a hallmark for GDP and Time interaction

Moving on this plane means that the relative speed of GDP change and time change is constant during the whole interval, so they grow with uniform distribution related to each other. It is because of that the plane makes a 45-degree angle with the Time or GDP axis on the 'Time-GDP' plane. If the path route were on a plane that creates a wider angle with the time axis – shaper with the GDP axis – it would mean that in this part of the time, the GDP is growing faster compared to its growth in the other time intervals. Similarly, whenever the data curve moves on a plane, which forms a sharper angle with the Time axis – more expansive than the GDP axis – the GDP grows slower compared to other periods (Fig. 2-4-2-1a).

Plane {'010', '011', '101', '100'}

This plane is a similar form to the previously discussed one. There are some differences, such as that moving on this plane implies there exists negative permanent uniform economic growth over time. Moreover, this plane creates a 135-degree angle with the time and GDP axes. If this angle were sharper with the time axis, the growth decline would be more severe in that period compared to other intervals (Fig. 2-4-2-1b).

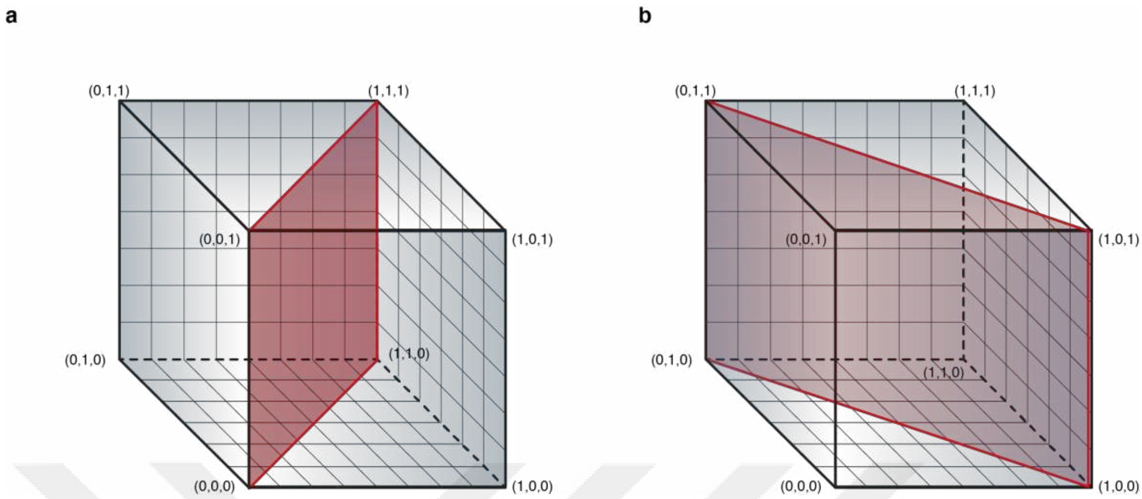

Figure 2-4-2-1. Two diagonal planes perpendicular to the x-y faces in the cube.
(a) The plane is illustrated as a manifestation for GDP and Time interactions. (b) This plane is similar to that of panel a, but is a hallmark of negative economic growth over time.

Plane ‘000’, ‘010’, ‘101’, ‘111’} as a hallmark for CO_2 emission and Time interaction

Moving on this plane indicates that the relative pace of CO_2 emission and time evolution is constant throughout the interval, implying that they grow with a uniform distribution. In other words, the plane creates a 45-degree angle with the Time or CO_2 emission axis. If the route is on a plane that makes a broader angle with the time axis – shaper with the CO_2 emission axis – it means that the CO_2 rises quicker in this portion of the time than it is in the other time intervals. Similarly, anytime the data curve travels on a plane that makes a sharper angle with the Time axis, the CO_2 emission growth rate in this phase would be slower than in the other periods (Fig. 2-4-2-2a).

Plane {‘001’, ‘011’, ‘100’, ‘110’}

Since this plane is vertical to the plane {‘000’, ‘010’, ‘101’, ‘111’}, there will be a uniform CO_2 emission decline over time. Moreover, this plane creates a 135-degree angle with the time and CO_2 emission axes. If the data curve were on a plane which creates a sharper angle with the time axis, the CO_2 emission decrease would be more severe in that period compared to other intervals (Fig. 2-4-2-2b).

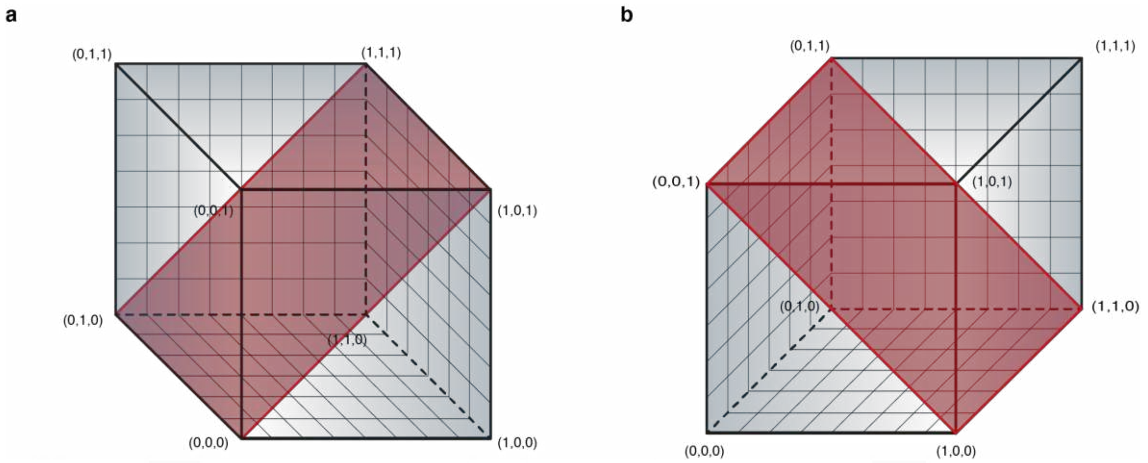

Figure 2-4-2-2. Two diagonal planes perpendicular to the x-z faces in the cube.
(a) The plane is illustrated as a manifestation for CO_2 emissions and Time interactions. (b) The red plane in this panel demonstrates a hallmark of a decrease in CO_2 emissions over time.

Plane {'000', '100', '011', '111'} as a hallmark for CO_2 emission and GDP interaction

Moving on this plane means that CO_2 emission and economic growth are increasing proportionately, implying a positive covariation between CO_2 Emissions and GDP growth. This plane creates 45-degree with GDP and CO_2 emission axis; it is the reason for CO_2 emission and GDP coordination in their growth path. In a case the data curve moves on a plane that creates a sharper angle with the GDP axis, the production growth relative to CO_2 emission growth speed would be higher than their relative speed in the whole change portions (Fig. 2-4-2-3).

Plane {'001', '101', '010', '110'}

Similar to the previous ones, this plane is perpendicular to the plane {'000', '100', '011', '111'}. Hence, in this case, by moving on the plane, CO_2 emission and production will correlate negatively. In other words, growing production with declining pollution or economic decline along with a rise in CO_2 emission will happen (Fig. 2-4-2-3).

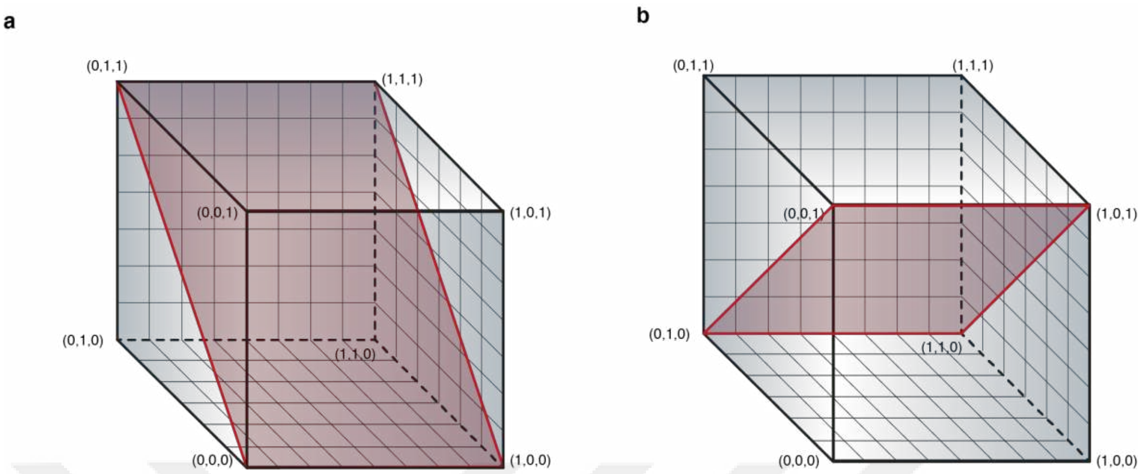

Figure 2-4-2-3. Two diagonal planes perpendicular to the y-z faces in the cube.
(a) The red plane illustrates positive correlations between CO_2 emissions and GDP. (b) In contrast, the red plane in this panel illustrates a negative correlation between the two.

In summary, in order to explain the data curve path continuously, we should first imagine the tangent plane on which the curve is moving, then evaluate the corresponding plane's angle with each feature's axis to determine how features evolve in the given period.

2.5 Vertices interpretation and distance measurement criteria

In the cube environment discussed, depending on which scenario the county plays, its distance from the vertices changes continuously. In other words, the distance from different vertices shows how a country evolves over time and toward which scenario the country is approaching. Hence, it would be valuable to specify each vertex's role in representing different scenarios. After that, it would be possible to understand the movement's dynamics by calculating and comparing the curve's distance from the vertices. This numeric data could also be deployed as a processed data resource to make predictions about the future trend.

2.5.1 Vertices interpretation

Vertex '0,0,0'

This point is the origin of the cube. According to the cube's structure, this point represents the lowest amount for each of the three features (axis). Since this vertex is the starting point for any data curves, they will diverge from it toward the others through their own paths. Hence, the importance of this vertex is that it shows that the countries also now have very distinct locations, historically, they were in the same position.

Vertex '1,0,0'

This point shows that the time axis reaches the most amount although the GDP and CO_2 emissions are in the lowest records. Moving toward this point will show a condition that both GDP per capita and emission per capita are in the same direction and both are decreasing over time.

Vertex '0,1,0'

The path of CO_2-GDP evolution would be close to this destination when the country has experienced enormous economic growth with limited CO_2 emissions in the past and little growth with massive emissions in the future.

Vertex '0,0,1'

Similarly, the distance from this point would be the lowest amount when in a part of a player's history there was an enormous emission growth without significant growth in GDP, but the trend completely changes and reverse in the future.

Vertex '0,1,1': Historical Growth

If both production and emission grow massively in a part of its history that would not be repeated in the future, the distance in those periods would be the lowest from this vertex. Hence, being close to this vertex means that the country has experienced historical growth in the past.

Vertex '1,0,1': Poor Environmental Management

This vertex would be an indication of the negative performance that over time there is not a significant amount of production, but the amount of emission is consistently increasing. Therefore, during periods that the country moves toward this vertex means that the player is increasing emission without significant positive return. This vertex would be an index for environmentally poor management.

Vertex '1,1,0': Environmental Kuznets Curve

This vertex will be the representative of the Environmental Kuznets Curve in the cube. Moving toward this vertex will show a scenario in which per capita GDP is increasing, but the emission per capita is decreasing. If a country consistently decreased its distance from this vertex, the existence of EKC for it would be validated. Hence, the distance from this vertex will be the main measurement to show if the country goes toward reaching the EKC hypothesis or not.

Vertex '1,1,1': Consistent Pollution-making Growth

This vertex is the most anticipated one. Moving toward it means that both per capita production and emission are increasing.

In order to understand the dynamics of a country's economic and environmental performance through time, we will find its data points' distances from all eight vertices in given years. After that, the analysis of this distance evolution will show us how the country has acted in different time intervals. Moreover, this numeric metric will help us to predict the pattern of the countries and the globe's environmental patterns. The following sub-section will discuss why the proper distance measurement metric for our purpose would be the Chebyshev distance and will explain Chebyshev space and distance in detail. We also will cover what the difference between this distance metric is in comparison to the traditional Euclidean one.

2.5.2 Distance Calculation Method

Chebyshev Distance

Chebyshev distance, often known as the maximum metric in mathematics, is a metric defined on a vector space in which the distance between two vectors is the biggest amount between their differences along any coordinate axis.

It is often known as chessboard distance because the minimum number of moves required by a king to move from one square to another equals the Chebyshev distance between the squares. This parity is reliable if the squares have unit length, as in the 2-D reference frame with axes aligned to the board's edges.

If the point's p and q in two dimensions, i.e., plane geometry, have Cartesian coordinates (x_1, y_1) and (x_2, y_2), their Chebyshev distance is:

$$D_{Chebyshev} = \max(|x_2 - x_1|, |y_2 - y_1|)$$

Similarly, the Chebyshev distance among two vectors or points x and y, having standard coordinates x_i and y_i, is calculated as follows:

$$D_{Chebyshev}(x, y) = max_i |x_i - y_i|$$

According to this metric, a square with sides of length '2r' and parallel to the coordinate axes is the set of points with Chebyshev distance 'r' from a center point. Likewise, in three-dimension space, a cube with segment length '2r' and parallel to the coordinate axes is equivalent to a sphere in Euclidean space with a radius of 'r'. In other words, in the 2-D Euclidean space, points on a circle with a radius of 'r' have the same distance from the origin. In Chebyshev space, the distance metric is square-based instead of circle-based, meaning that points on a square from the origin have the same distance from it. Similarly, in the 3-D Chebyshev space, the metric is a cube instead of a sphere.

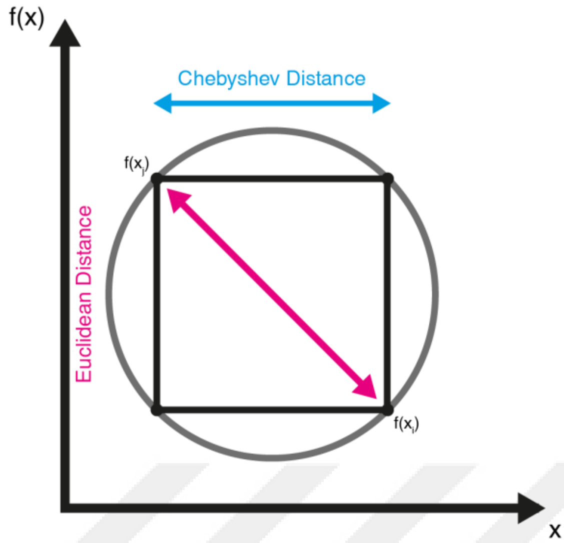

Figure 2-5-2. *Euclidean and Chebyshev distance comparison.*
Illustrated in a two-dimensional space, the figure shows how Euclidean distance is different from that of Chebyshev. In Euclidean space, square sides (black lines) are equal in length but are smaller than the square diagonal (magenta); however, the Chebyshev length of sides (blue) and Chebyshev diagonal are equal for a given square. Also, the Chebyshev distance of any given point on a square to its center is equal. Hence, a Euclidean circle (in grey), per definition, is equivalent to a Chebyshev square (in black).

2.5.3 Chebyshev Space subareas in detail

On the two-dimensional space

As shown in the Fig. 2-5-3-1, the distance of a random point 'A' – with Cartesian coordinates (40, 10) - from all vertices on the 2-D plane has been depicted. The Chebyshev distance of point 'A' from each vertex would be the length of a square that crosses the corresponding vertex and the point 'A'.

To calculate the distance from the origin with Cartesian coordinates (0, 0), the Chebyshev distance would be:

$$D1 = \max\ (|40 - 0|, |10 - 0|) = 40$$

For simplicity, we assume that the Cartesian coordinates of the other vertices would be (100, 0), (0, 100), and (100, 100). However, in the cube environment, the edges would be unit scaling from 0 to 1, and features would be normalized to this scale. Assuming that the distance from vertices (1, 0), (0, 1), and (1, 1) would be D2, D3, and D4, respectively, we could calculate them as below:

$$D2 = \max\ (|40 - 100|, |10 - 0|) = 60$$
$$D3 = \max\ (|40 - 0|, |10 - 100|) = 90$$
$$D4 = \max\ (|40 - 100|, |10 - 100|) = 90$$

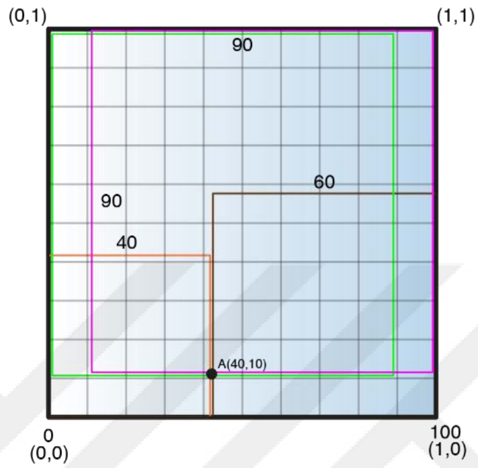

Figure 2-5-3-2. An example of calculating the Chebyshev distance from vertices of a square.
As illustrated in the figure, the Chebyshev distance between a given vertex and a point (e.g. point 'A') in is equal to the length of a square with the identical vertex, which intersects with the desired point.

Different points' distances from vertices split the plane in the Chebyshev space into the four sub-areas. As illustrated in the Fig. 2-5-3-2, points on the 'area one' have the same distance from the vertices (1, 0) and (1, 1). Similarly, the points in the 'area two' have the same distances from the vertices (0, 0) and (1, 0). Moreover, points in 'area three' have equal distances from vertices (0, 0) and (0, 1), and points in 'area four' are equally far from vertices (0, 1) and (1, 1).

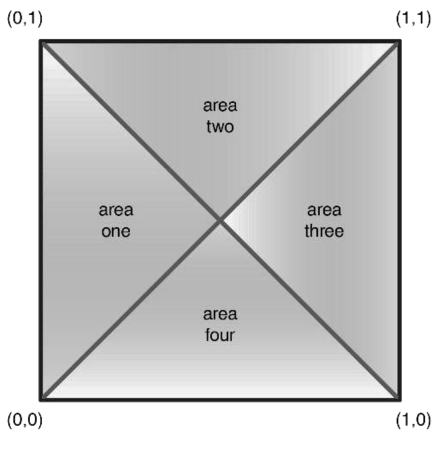

Figure 2-5-3-2. Segments of space in a two-dimensional Chebyshev unit square.
As designated by four areas, the Chebyshev distances between any given point in an area and its two distant vertices are equal.

On the three-dimensional space

In the three-dimensional cube-based space, the Chebyshev distance pattern would split the cube into twenty-four sub-spaces. These subspaces result from the collision of the inner six planes of the cube. As shown in the Fig. 2-5-3-3, these planes split the cube's environment into twenty-four spaces wherein the pattern of the Chebyshev distance from different vertices would be the same. Hence, there would be twenty-four different patterns for the Chebyshev distance behavior in the cube (Fig. 2-5-3-3).

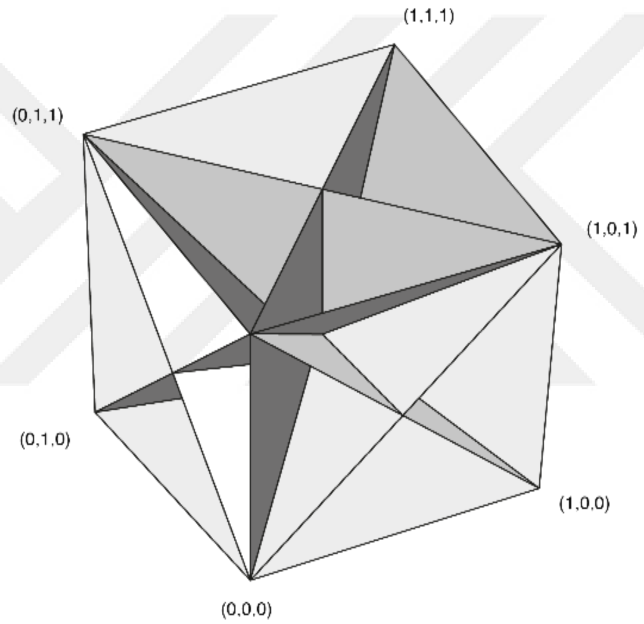

Figure 2-5-3-3. Subspaces of a three-dimensional unit cube in the Chebyshev space.
The same concept of Fig. 2-5-3-2 in a three-dimensional Chebyshev space which has resulted in 24 segments in the unit cube.

2.6 Introducing absolute and relative environments

Until now, only the historical performance of a country in the cube environments has been illustrated. The critical point about these cubes is that the edges' scale would be determined by the country's performance in its history. In other words, the minimum and the maximum number of edges will be specified based on the countries' lowest and highest recorded data. These cubes will be used to determine the absolute performance of each player according to its historical performance.

However, there would be a relative cube environment to examine the performance and interaction of all countries over time. In the relative cube, the data curves of all countries will be depicted in one joint unit cube. Hence, outlier countries will determine the edges' scale, and consequently, this issue will distort the other data curves and their distances from vertices. The emphasis in the relative environment would be on the examination of countries' performance in comparison to other ones. In other words, in the absolute cube, a player's performance would be examined according to its history. Nevertheless, in the relative environment, each player's performance would be inspected based on the performance of all other players (Fig. 2-6-1-1).

By examining the absolute environment solely, there would be ignorance regarding a country's relative performance compared to others. The importance of the relative cube is that it determines how significant a country's impact is on the global scale. Since the environmental problems, such as CO_2 emissions, have global scales, the unawareness regarding the relative performance of countries could be misleading. Accordingly, it sounds necessary to consider relative space to supplement the absolute space.

2.6.1 The importance of combination of absolute and relative spaces

Fig. 2-6-1-1 shows country A, B, and C's absolute cubes and their relative space cube. As we focus only on absolute cubes, it might sound that 'country A' has been performing better than others since its CO_2 increase speed is declining. On the other hand, country C might be considered the worst performer as its recent performance illustrates a sharp rise in the CO_2 emission rate. Although these results are entirely factual if we examine the countries' performance regarding their previous history, there would be deceptive if these results were generalized in comparison to each other. Because of their different intensity on the global scale, their comparative examination should be normalized; otherwise, utilizing the absolute space's results will be utterly slippery. The relative cube performs the necessary normalization process to make comparable results. As the relative cube shows, the country 'C', despite its recent destructive performance, has minimal impact on the CO_2 emissions on the global scale. On the other hand, Country A still has a vast worldwide degradation effect, although it has performed better than in the past.

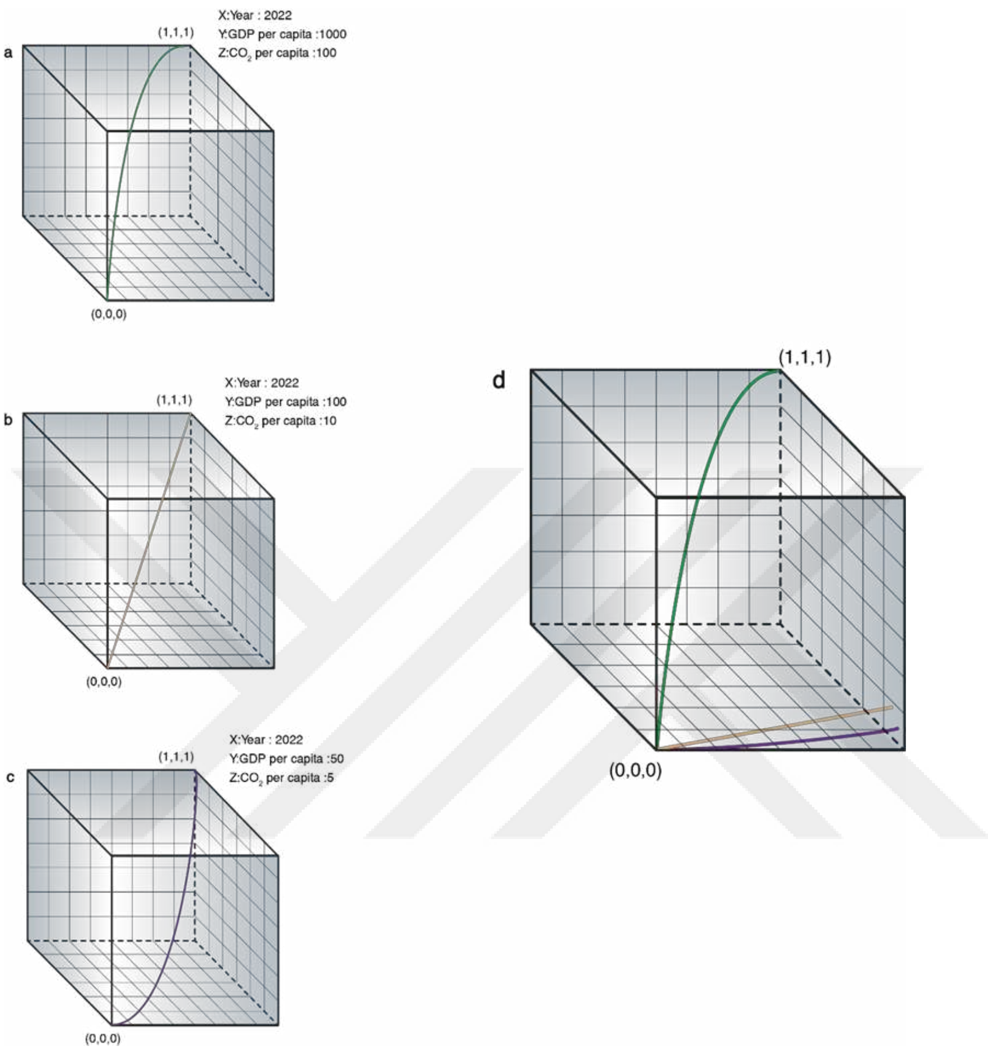

Figure 2-6-1-1. Absolute and relative environments.
(a) An exemplary country with leading GDP and CO_2 emissions is shown in the absolute environment. (b) The second exemplary country is shown with a linear growth in the absolute environment. (c) The third exemplary country is shown with an exponential growth in the absolute environment. (d) Plotting the countries in panels a-c in the relative environment will provide a better insight of the comparative contribution of countries. Please note that the curves that are illustrating countries shown in panel b and c are squeezed in panel d, as their relative GDP and CO_2 emissions are negligible.

2.6.2 The manner of outlier data impact on the other players

When several countries with separated absolute data curves join together to make relative curves, the scale of the edges of the relative cube would be specified according to the most divergent country in that feature. Therefore, at most, only one country would have the identical curve as of its absolute environment, and the others would be changed. The following three figures will show how the data curve of the convergent country changes according to the extent of divergence of the other. Moreover, it is indicated that the curve's change could be based on only one feature's rescaling or both.

Suppose the rescaling happens in the feature related to the dimension Z. In that case, the more convergent country in terms of the feature represented on the dimension Z will rotate its curve toward the plane {'0,0,0', '1,0,0', '0,1,0', '1,1,0'} as shown in the Fig. 2-6-2-1.

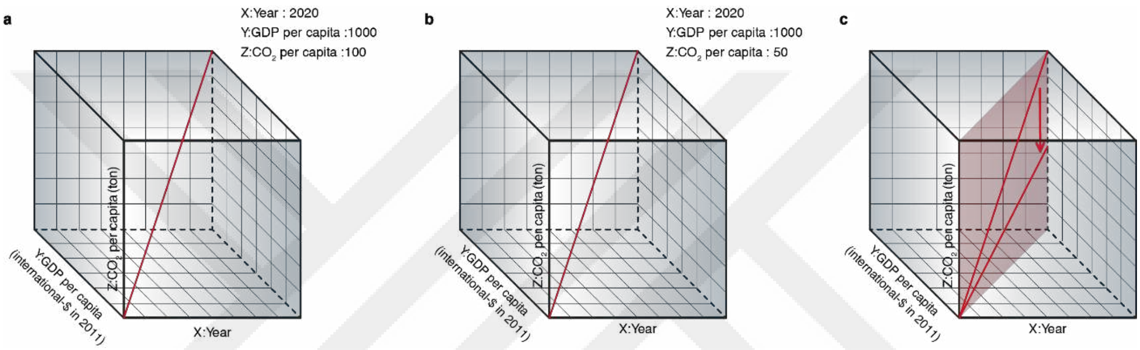

Figure 2-6-2-1. Rescaling along the Z axis in the relative environment.

Similarly, if the rescaling occurs in the feature related to the dimension Y, the more convergent country in terms of the feature denoted on the dimension Y will rotate its data curve to the plane {'0,0,0', '1,0,0', '0,0,1', '1,0,1'} as displayed in the Fig. 2-6-2-2.

Finally, if a country would be convergent in both features compared to the other one, it would rotate both rotations discussed at the same time (Fig. 2-6-2-3).

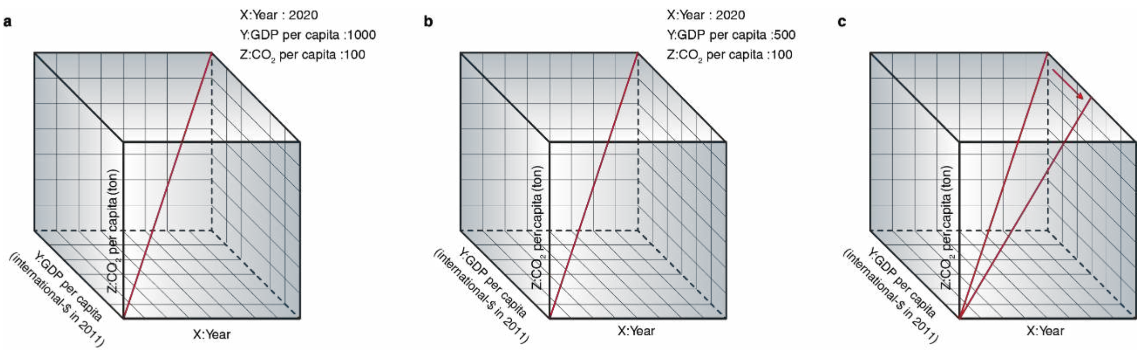

Figure 2-6-2-2. Rescaling along the Y axis in the relative environment.

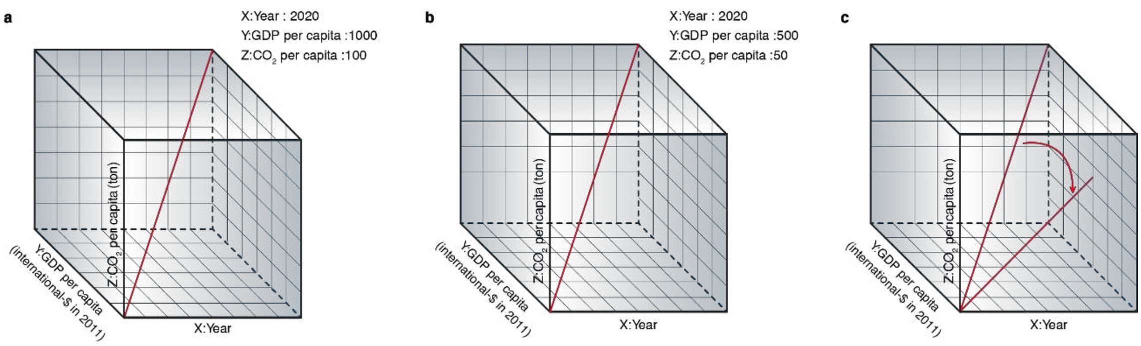

Figure 2-6-2-3. Rescaling along both axes of Y and Z resembles a rotational transformation in the relative environment.

2.7 Review of the section

In conclusion, each nation is represented in two distinct cube settings. The first would be an individual space, and the second environment would be a relative separation. Afterward, for all available data points in both settings, the Chebyshev distance from all eight vertices would be computed. We will proceed further analysis on these two sets of distance data to categorize countries' different performance patterns. The details of the manner of analysis and its interpretation and results will be discussed in the following section.

Chapter 3:

RESULTS AND DISCUSSION

The nations of the globe are examined and analyzed in two phases. First, distance measurements are computed for all countries, and their raw results are provided in the supplemental section. Moreover, for nations whose CO_2 emissions share in the world is more significant than 0.5 percent, the explanation and comparison of results will be discussed thoroughly in this section. This filtration aims to examine and compare the profile of the more responsible players in the world economy in more detail.

3.1 General View

Countries with CO_2 emission share of more than 0.5 percent include China, United States, India, Russia, Japan, Germany, Canada, Iran, South Korea, Indonesia, Saudi Arabia, Brazil, Mexico, Australia, South Africa, Turkey, United Kingdom, Italy, France, Poland, Taiwan, Thailand, Malaysia, Spain, Ukraine, Kazakhstan, Egypt, United Arab Emirates, Vietnam, and Argentina, respectively.

These countries are responsible for about 85 percent of global CO_2 emission and more than 84 percent of global GDP. As indicated in Fig. 3-1-1, the countries with the highest worldwide CO_2 emissions shares are from high-income or upper-middle income groups.

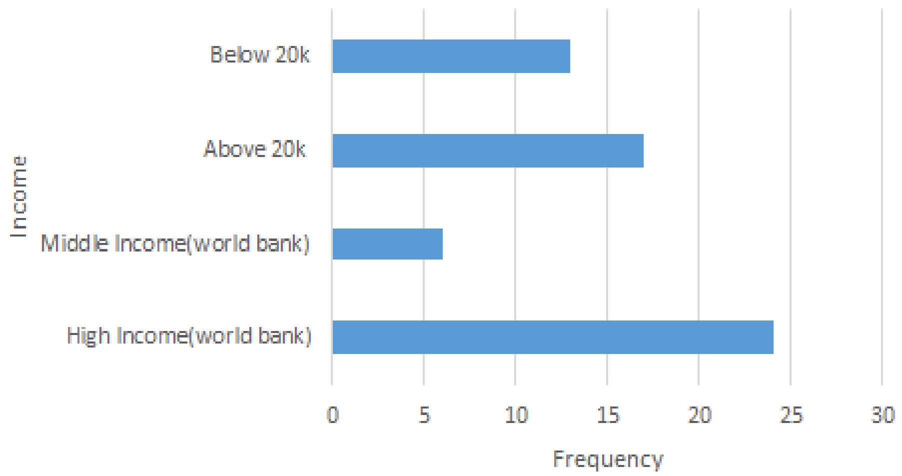

Figure 3-1-1. The average income distribution of countries with global CO_2 emission share of more than 0.5 percent.

The upper middle cluster is defined by the world bank as nations having per capita incomes over $4,096, on average. Additionally, people from high-income nations will be among those who pass the $12,695 threshold. According to this criteria, six of the thirty nations make up the upper middle cluster, while twenty-four belong to the high-income category. Additionally, since in Environmental Kuznets Curve literature, many studies refer to an approximate income level of $20,000 as the turning point, Fig. 3-1-1 indicates that seventeen countries reached this level, and thirteen countries are below this threshold in 2018.

In addition, as shown in Fig. 3-1-2, the variety across nations has steadily risen over time, in addition to the average growth in national income. The income range between these thirty nations was around $20,000 in 1960, but it is now above $70,000.

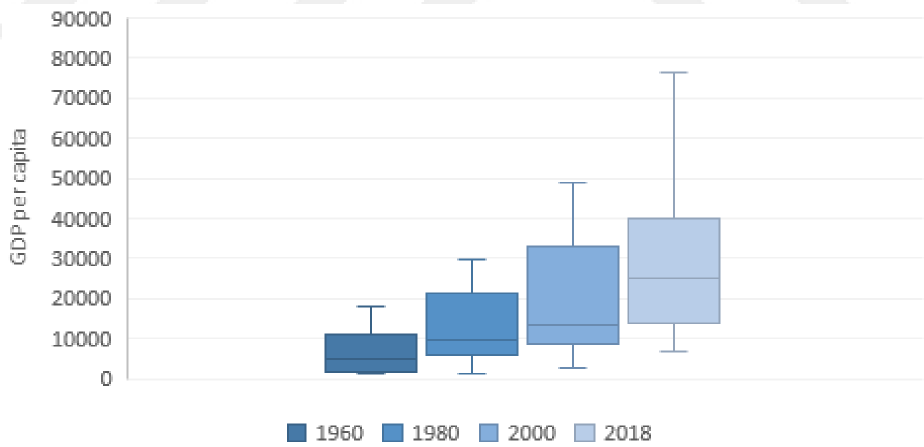

Figure 3-1-2. The average income box plot distribution of countries with global CO_2 emission share of more than 0.5 percent.

Figure 3-1-3 displays the scatter distribution of CO2 emissions and per capita income for all thirty countries. The figure illustrates the positive correlation between two features in 2018. The nations with the highest income levels also have the highest CO2 emission statistics. All countries with CO2 emissions per capita larger than 14 tons, with one exception, have incomes of more than 40,000 dollars. Furthermore, all nations with wealth levels of more than 40.000 dollars produce at least 12 tons of CO_2 per person, except in one case.

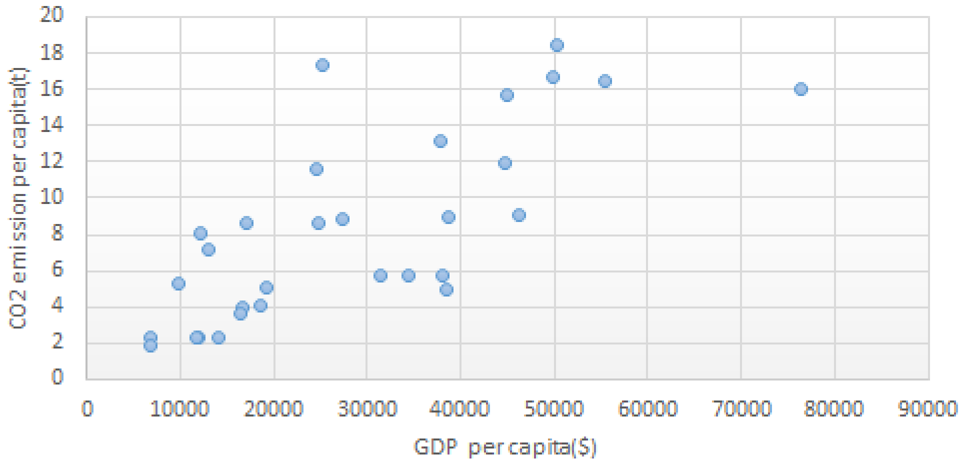

Figure 3-1-3. The average income and CO2 emission scatter plot for countries with global emission share of more than 0.5 percent in 2018.

3.2 Clustering of Countries

3.2.1 Clustering Procedure

According to their historical evolution paths, as was stated in the previous chapter, various nations experience unique distances from each vertex. Each nation is categorized into one of the groups by computing the Chebyshev distances, examining their trend, and comparing them with the predetermined patterns. If a player's route does not fit into one of the predefined classes, it will establish a new cluster that will serve as the foundation for all subsequent cases.

For instance, the Fig. 3-2-1-1 represents the real data curve for China, whereas the Fig. 3-3-1-2 demonstrates how it differs from the vertices (0,0,1) and (1,1,1) over time. As shown, China's behavior resembles the 'recent intensive growth deterioration' pattern because its distance trend initially reduces from vertex '1,0,0' and '1,1,1', but then it travels away from the vertex '1,0,0' while continuing to approach '1,1,1'. It could be also useful to emphasize that pattern recognition analysis is based on distances from all vertices, and that the development of just two vertices is being illustrated here for simplicity's sake.

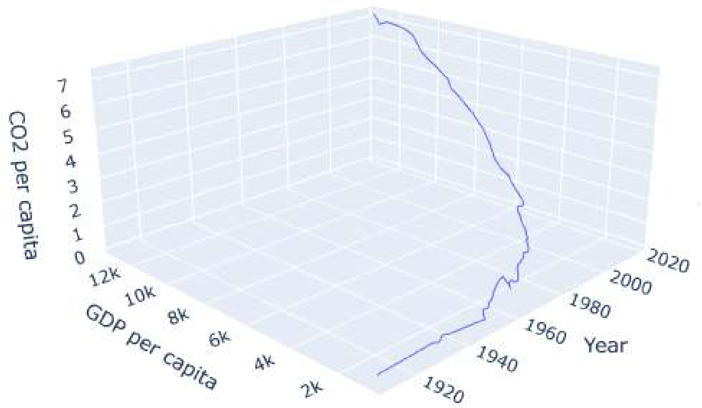

Figure 3-2-1-1. China's average income and CO_2 emission course over time

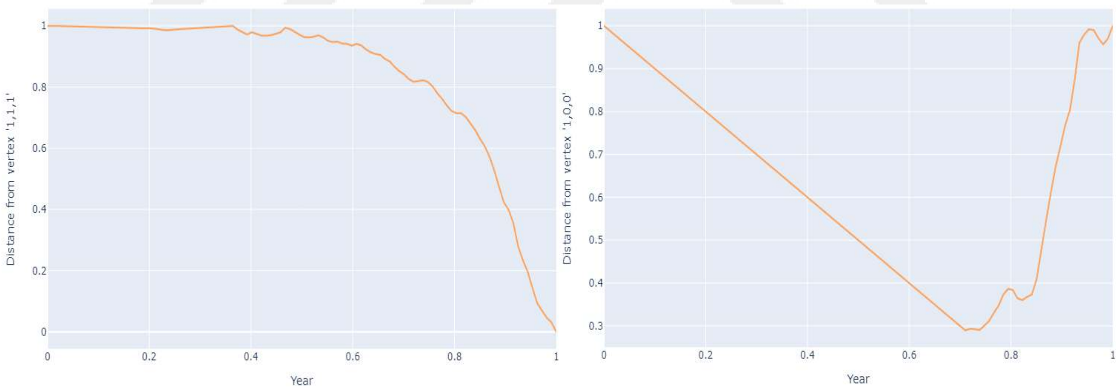

Figure 3-2-1-2. China's income-CO2 course's distances from the vertex "1,1,1" (left) and the vertex "1,0,0" (right) over time.

3.2.2 Clustering Results

Countries are classified into six patterns using distance analysis. With ten countries out of thirty, the 'recent massive growth-degradation' pattern had the largest members. Seven countries were grouped as the nominates for the existence of the Environmental Kuznets Curve. The discussion below provides the results in more depth for each cluster.

Equivalent cluster to 'recent massive growth-degradation'

The cluster of recent massive growth-degradation is the most frequent pattern between the countries. China, South Korea, Taiwan, Thailand, India, Malaysia, Indonesia, Vietnam, Turkey, and Egypt are a group of countries whose trends are increasing level of economic growth along with increasing CO_2 emissions during the course of their histories (Fig. 3-2-2-1).

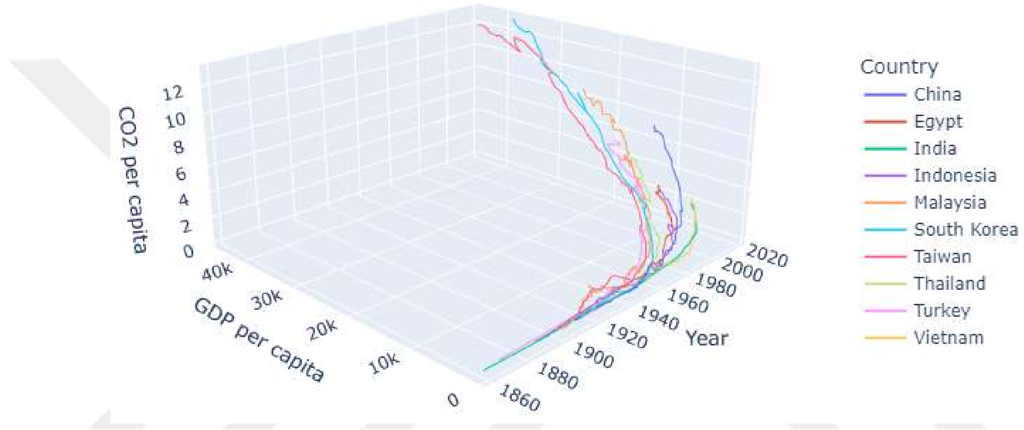

Figure 3-2-2-1. The illustration of income-CO2 courses for countries of the cluster "recent massive growth-degradation" in the relative space.

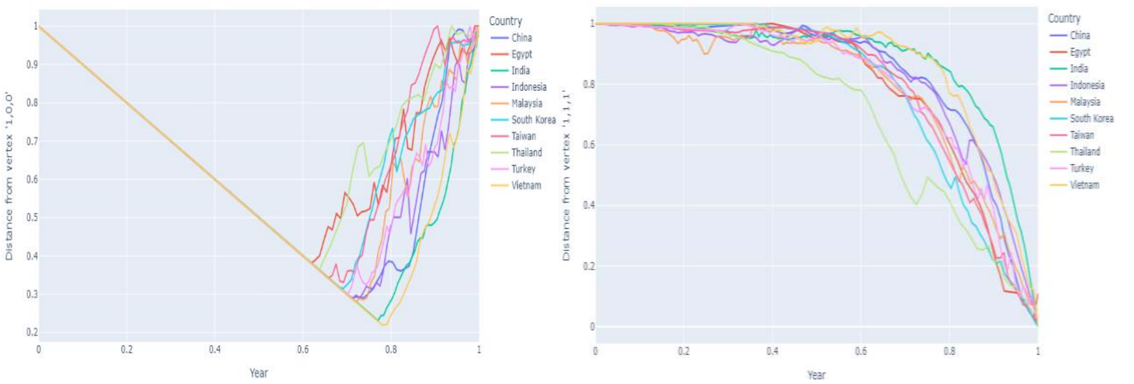

Figure 3-2-2-2. Distances from the vertex "1,0,0" (left) and the vertex "1,1,1" for countries of the "recent massive growth-degradation" category.

In this cluster, countries like Taiwan and South Korea have reached the group of high-income nations, with GDP per capita estimates of \$44,600 and \$39,200, respectively. Numerous studies in the literature suggest that the GDP level of \$20,000 per capita marks the turning point for the nominated countries in case of EKC existence. However, Taiwan, South Korea, and Malaysia, with much more income levels, still show covariance between GDP growth and CO_2 emission. The modal predicts that other nations in this group, including China, India, Turkey, Egypt, Indonesia, Thailand, and Vietnam, may not see a decoupling of GDP growth and CO_2 emissions, even at higher income levels, because their evolutionary trajectory is similar to that of the GDP leaders in the group, which are South Korea, Malaysia, and Taiwan.

Like other group countries, Turkey's Growth-CO_2 path exhibits a favorable covariance between two characteristics. Turkey only differs from other countries in one aspect that it has gone through more volatile periods during which the growth rate was negative.

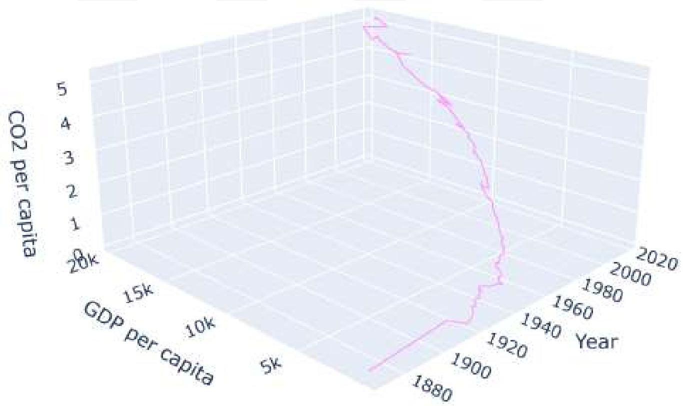

Figure 3-2-2-3. The Illustration of Turkey's income-CO2 course over time.

Equivalent cluster to 'Fluctuating growth and emission'

This group comprises Argentina, Iran, South Africa, and Saudi Arabia. The pattern of 'permanent growth and CO_2 emission' among predefined behaviors is the closest pattern to this cluster. Although this cluster has similarities with the previous one, there are some differences. The positive correlation between GDP and CO_2 emission is still established in this cluster, but its extent is not as strong as it was in the previous cluster. Additionally, there has not been much of a recent increase in the rate of economic growth for this group's members. In other words, their present growth trajectory is comparable to their previous one. This is why their data points do not approach the vertex '1,0,0'. Additionally, this group of nations has had more environmentally turbulent eras throughout its history. Fig. 3-2-2-5 shows the Growth-CO_2 curve of Argentina as an instance of this cluster.

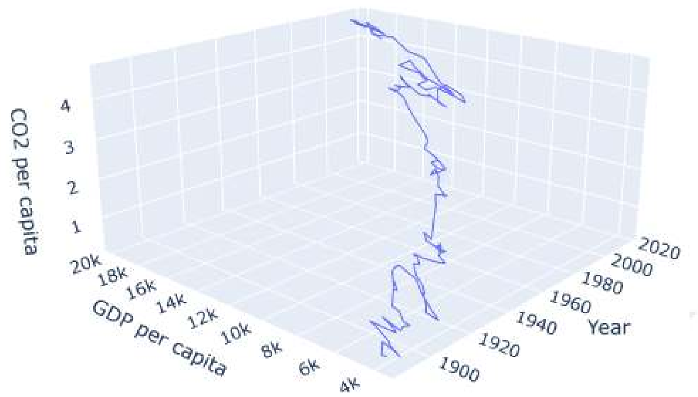

Figure 3-2-2-4. The Illustration of Argentina's income-CO_2 course over time.

Cluster of time disjuncture: patterns combinations

As a result of the clustering, Russia, Ukraine, and Kazakhstan are placed in the same cluster. As seen in the Fig. 3-2-2-5, although there is a positive correlation for the entire time, the whole period is split into three distinct courses. Positive growth occurs in the first and final phases, bringing countries closer to the vertex '1,1,1', which indicates that growth and CO_2 emissions are rising together. Although, in the middle phase, they move toward the vertex '1,0,0' because of declining economic growth and CO_2 emission. However, the evident distinction between the first and final phases is that the latter is significantly more effective than the former. In the beginning, there is a considerable rise in CO_2 emissions for a negligible economic growth, but in the end, for much higher rates of economic growth, the rise in CO_2 emissions is negligible (Fig. 3-2-2-5).

Equivalent Cluster to Environmental Kuznets Curve

As a result of the clustering, a group of nations that includes the United Kingdom, France, Germany, United States, Australia, Japan, and Canada are categorized as members of the 'Environmental Kuznets Curve' category, albeit with different degrees of compatibility. According to the Environmental Kuznets Curve hypothesis, for the EKC observation,

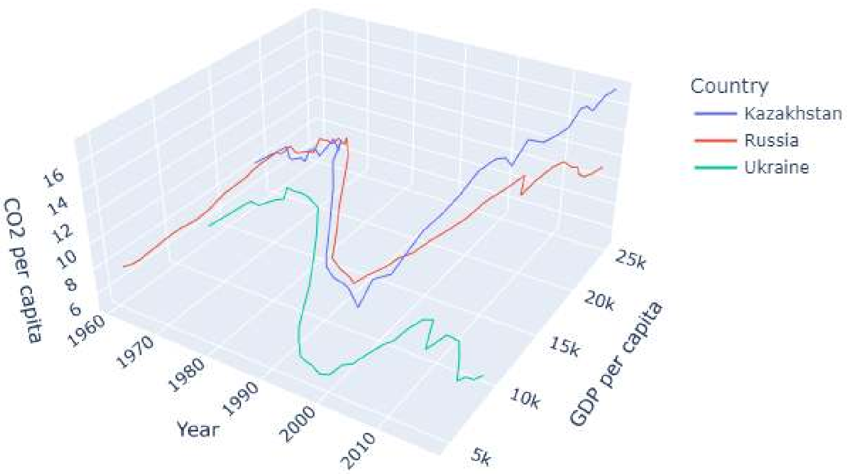

Figure 3-2-2-5. The relative cube presentation for countries of the cluster "time disjuncture"

there should be an initial rise in both GDP and CO_2 emissions. However, throughout the secondary phase, economic growth should continue to rise while CO_2 emissions decline. In the unit cube environment, this implies that the country's distances from the vertex '1,1,1' should initially be decreasing, but that they should increase from a point known as the turning point. This turning point occurs in the EKC nominee countries at various intervals, as depicted in the Fig. 3-2-2-6. France was the nation that turned the fastest, and the United Kingdom was the nation that managed to escape this vertex the most successfully.

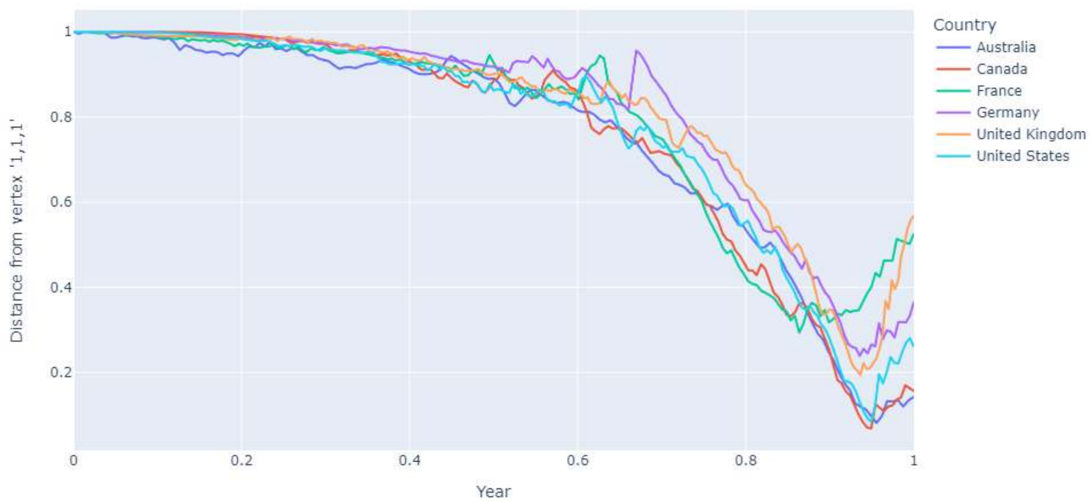

Figure 3-2-2-6. The distance from the vertex "1,1,1" for countries of EKC cluster over time.

For analysis of EKC observation, the distance of vertex ‘1,1,1’ is meaningful if it is examined along with the distance from the vertex ‘1,1,0’, named as EKC vertex. Actually, the distance from EKC indicates the closeness to the optimum of EKC, so it gives a numeric unit of measurement to show how far the countries are from the condition of consistent and permanent economic growth along with decreasing carbon emissions.

As the Fig. 3-2-2-7 demonstrates, although group countries’ recent distance trend from the EKC vertex has been declining, so they show the EKC behavior, their absolute distances vary. The distance only for the United Kingdom and France has been decreasing consistently in a way their current distance is less than their distance from the vertex of ‘1,1,1’. Germany and the USA show somehow close patterns. They have experienced a relatively long period in showing the EKC trend, although they are still closer to the vertex ‘1,1,1’ than the EKC vertex. And finally, Canada, Japan and Australia show a very weak EKC pattern. Because they have only recently begun to exhibit this pattern, it is possible the trend will disappear soon and that GDP and carbon emissions will once more be coupled, creating the ‘N’ pattern. This observation has been prevalent throughout the history of many nations, such as the USA and Japan. Hence, they could not with certainty yet be deemed EKC cases since their recent trend is new, and the distances still are too far from the EKC vertex compared to the ‘1,1,1’ vertex. This issue in less extent exists in Germany and USA.

Figure 3-2-2-7. The distance progression of EKC categorized countries from the vertex "1,1,0".

Moreover, as shown by the Fig. 3-2-2-8, different turning points occurred along the growth route of the countries. The first two nations that demonstrated a decoupling between growth and carbon emissions were the United Kingdom and France. With a GDP per capita of roughly \$18,000 and \$20,400, respectively, they reached a turning point after 1972. Their respective carbon emissions per capita were approximately 11.6 and 10.3 tons. Germany began reducing carbon emissions a little later, in 1979, with a GDP per capita of roughly \$22,300 and 14.25 tons of CO_2 emissions. However, the United States' peak CO_2 emission level was later in 2000. It reached its maximum emission level with 22.3 tons of CO_2 emissions for a GDP per capita of \$45,900.

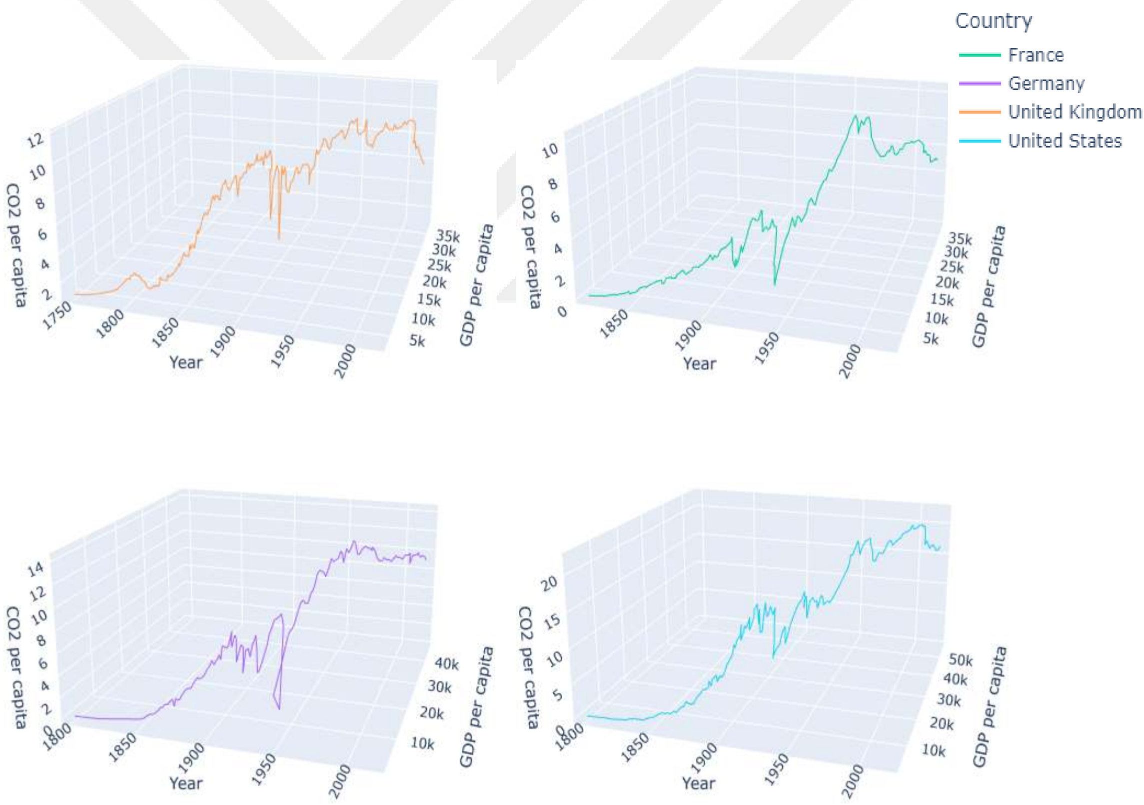

Figure 3-2-2-8. The illustration of income-CO_2 course for EKC classified countries.

In total, before 1980, the economies of France, Germany, and the United Kingdom reached a turning point with income level of \$20,000 per capita. However, the US began to reduce its CO_2 emissions after 2000 and at a higher income level of \$45,900. Therefore, two conclusions about the time difference and GDP can be drawn. The early countries where the EKC pattern trend is seen include France, the United Kingdom, and Germany.

Second, there are two possible outcomes for the recent observed trend involving the USA, Canada, Japan, and Australia. If they can maintain their declining carbon emission trend, these countries will be regarded as the second wave of CO_2 EKC observation, with a turning point after \$40,000 per capita income. However, if their CO_2 emission direction changes back to an upward trend, which has been the case in their history, the three European countries will remain the only EKC examples for CO_2 in the world.

The Fig. 3-2-2-9 indicates Japan's Growth-CO_2 curve as an example of a temporary EKC pattern in its history. Japan showed a falling carbon emission pattern from 1973 to 1987 along with consistent GDP growth, which sounds to be an EKC case. After 1987, though, the trend shifted to rising CO_2 emissions, forming a 'N' shape. It is the reason the current status in Australia, Canada, Japan, and the USA cannot yet be regarded as certain EKC observations. These countries by no means meet the requirement that their distance from the EKC vertices be closer than '1,1,1.' However, the USA has significantly reduced its distance from the EKC vertex among these four nations, and it is more likely than the others to keep up its current trend.

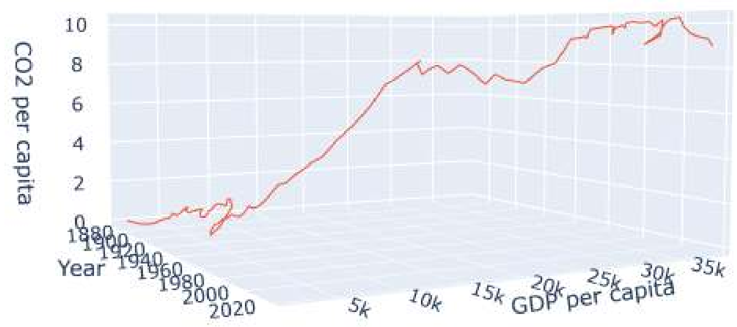

Figure 3-2-2-9. The Illustration of Japan's income-CO_2 course over time.

Cluster of recent negative growth and emission

This cluster includes Brazil, Spain, and Italy. The primary characteristic of this group is that for the most of their history, growth and emission have been positively correlated. Additionally, a recent trend for them would be decreased income and declining carbon emissions. They moved away from the vertex '1,1,1' due to negative economic growth, but because they did not go toward the vertex '1,1,0,' but rather '1,0,0,' their curve diverged from the EKC pattern. It serves as an illustration of why the pattern cannot be identified solely by the distance from vertex '1,1,1' (Figure 3-2-2-10).

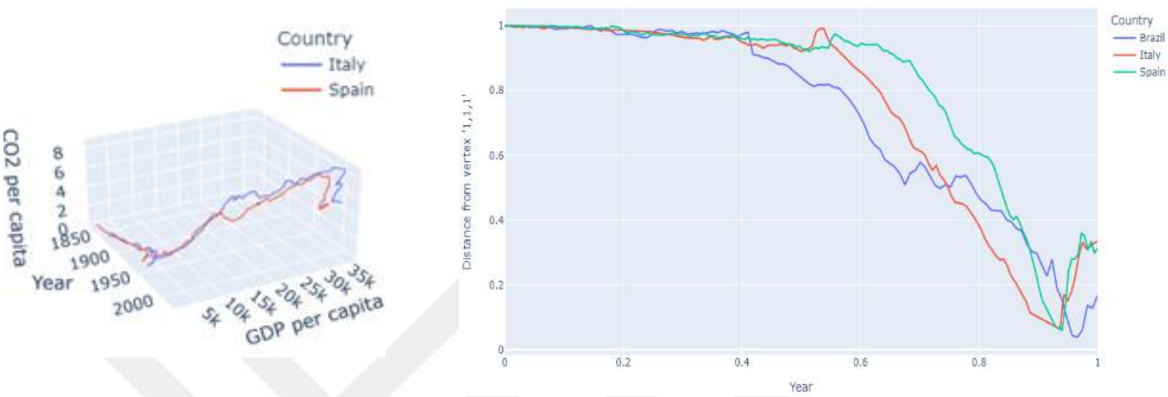

Figure 3-2-2-10. The income-CO_2 depiction and the distance evolution from the vertex "1,1,1" for Italy and Spain

Cluster of independency pattern

United Arab Emirates, Poland, and Mexico demonstrate a pattern in which economic expansion coexists with steady CO_2 emission levels. In other words, the recent data points have weak positive/negative correlations, and economic expansion has continued without noticeably increasing or decreasing CO_2 emissions. However, there is an essential difference between the United Arab Emirates with the others. The stable level of CO_2 emissions in UAE has been between sixteen to twenty tons, a record among countries under study. However, Poland and Mexico exhibit the same pattern for far lower emissions levels. Poland, from 1998 to 2018, has increased its average income from about \$11,400 to \$27,500 with no increase in its carbon emissions. Its CO_2 emission has been stable at about 8.8 tons per capita over the last two decades. In other words, Poland has shown that more than 140% increase in income could be achieved without any increase in emissions level. Similarly, Mexico seems to have a successful environmental management. In the last two decades, Mexico has kept its emissions level at a relatively low level of 3.6, which is one of the lowest records among countries. At the same time, its income increased from about \$11,000 to \$16,500. It means a fifty percent increase in GDP with keeping the emission amount at 3.6 tons per capita (Fig. 3-2-2-11).

Since Poland and Mexico have demonstrated that moving from a middle-cluster to a high-cluster income bracket can occur without a permanent or initial increase in carbon emissions, their situations may present a precious chance for developing nations to learn from and apply their lessons.

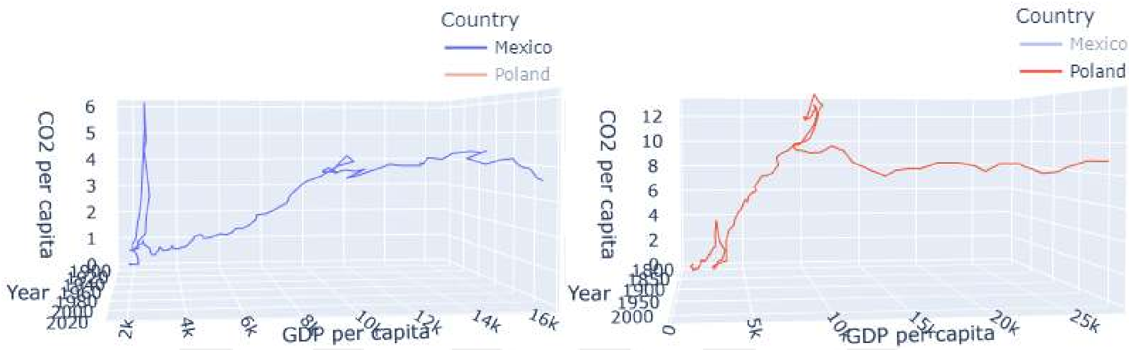

Figure 3-2-2-11. The depiction of income-CO2 course for Poland and Mexico.

3.3 Efficiency Analysis: Relative Examination

Up to this point, the focus of our analysis was centered on assessing a nation's performance in perspective of its historical records. Therefore, in the absolute cube environment, the evolution of a country's distances from vertexes was calculated and analyzed. However, it would be misleading to use these results to compare countries in relation to one another. It means countries with similar patterns could pass the same income levels with significantly different amounts of carbon emissions. Therefore, to enable cross-country comparison, it is necessary to normalize countries' pathways. The relative unit cube is the environment where the normalization process has been done, and afterwards, countries' relative analysis will be examined based on the same scale. This process provides the space to analyze countries' environmental efficiency during their course toward achieving high levels of income.

The Growth-CO_2 curve of France and Germany has been shown in the Fig. 3-3-1. The pattern of both countries is similar in a way they have experienced initial trend of permanent growth with increasing emissions levels and then, their growth has been continued with decreasing amount of CO_2 emission. However, France has reached and

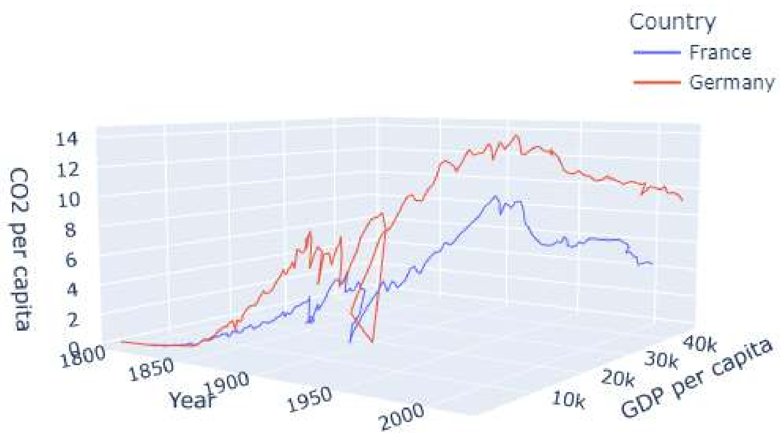

Figure 3-3-1. The comparison of France and Germany's income-CO_2 courses in the relative space

passed the same income levels with much less amounts of emissions. In other words, its growth path has been environmentally more efficient than Germany. It shows that by examining countries' courses and their distance progression in this space, we could consider the environmental efficiency degree of countries' growth compared to others. In this instance, since France has done more environmentally friendlier than Germany, it is closer to the relative EKC vertex. This explanation shows that although the absolute space illustrates the pattern of countries' performance according to their past, it could not provide the opportunity for their relative comparison since their scales are different and should be normalized before assessment. This example was one instance of possible relative analysis, demonstrating the significance of the relative cube because it not only displays historical data but also provides space for cross-national comparison.

3.4 Numeric indicator defining for EKC analysis in high-income countries

Considering the Environmental Kuznets Curve hypothesis and literature, initial growth is a precondition to observing environmental improvements. In other words, the average income should reach a high-level income, and a decrease in carbon emissions might be seen afterward. Hence, low-income and middle-income countries are not the subjects of EKC observation since they have not yet passed income boundaries. On the other hand, high-income countries are expected to start their path toward reducing carbon emissions while keeping economic growth positive. In the unit-cube space, if this scenario happens, the country will go closer to the EKC vertex, as discussed before. Therefore, the distance from this vertex could be considered a numeric index to show how far a country from this scenario is. Moreover, by defining this numeric indicator, it would be possible to monitor a country's trend consistently and its progress direction compared to its performance in the past.

However, if this numeric index is used to compare countries, it could be misleading. For this purpose, the distance of the EKC vertex in the relative space should be considered, as discussed earlier. The related information is provided in the appendix section. All in all, the distances from EKC vertex in both absolute and relative have essential interpretations. These indexes provide a criterion to observe if a country is moving closer or away from the EKC scenario compared to its past or other countries.

Table 3-4-1 shows the selected countries' distance from the EKC vertex in the absolute space. These countries are those that exceed or reach an average income level of twenty thousand in their history. The threshold of twenty thousand is considered based on the literature they show in case of EKC existence for any pollutants; it would occur after a turning point in the range of fifteen to twenty thousand dollars. Among the thirty countries discussed, nineteen have ever exceeded the boundary. Since they have already demonstrated the prerequisite of early growth, their distances are displayed numerically to demonstrate how distant they are from the scenario.

	2014	2015	2016	2017	2018
Argentina	0,9298131	0,9407921	0,9205855	0,8905241	0,8403346
Australia	0,8454792	0,8412494	0,8590888	0,8424501	0,8325583
Canada	0,7886932	0,7810320	0,7369320	0,7470213	0,7578642
France	0,3719101	0,3769232	0,3816736	0,3862928	0,3580287
Germany	0,6412696	0,6410236	0,6421107	0,6235509	0,5889942
Italy	0,6655123	0,6861867	0,6789920	0,6688472	0,6620024
Japan	0,9591715	0,9277490	0,9134052	0,9026422	0,8682862
Kazakhstan	0,8811822	0,9146205	0,8883621	0,9832018	1,0000000
Malaysia	0,9961652	0,9297649	0,9922440	0,9786434	1,0000000
Poland	0,5759431	0,5841620	0,6099286	0,6411139	0,6401776

Russia	0,7449896	0,7329645	0,7028736	0,7999210	0,9660701
Saudi Arabia	1,0000000	1,0000000	0,9252431	0,9071843	0,8664112
South Korea	0,9866787	0,9896980	0,9928758	1,0000000	1,0000000
Spain	0,6403014	0,6853263	0,6572636	0,6934105	0,6798188
Taiwan	0,9622505	0,9577400	0,9691614	0,9851787	0,9758417
Turkey	0,9878562	1,0000000	1,0000000	1,0000000	0,9700823
United Arab Emirates	0,7849983	0,7878564	0,7893993	0,7953563	0,7975171
United Kingdom	0,2132980	0,2289587	0,2314857	0,2385479	0,2425899
United States	0,6106150	0,5638022	0,5246010	0,5065679	0,5394512

Table 3-4-1. Chebyshev distance between data points of high-income countries and the EKC vertex in years 2014 to 2018.
Colors visualize the distances from the EKC. Green spectrum designates close distances to the EKC vertex, while red spectrum codes for large Chebyshev distances.

The table and its heatmap presentation reveal that, on a scale of zero to one, most countries are farther away from the EKC vertex than 0.8. It means that their growth and carbon emission trends still move together. The United Kingdom and France are the two countries that they have consistently moved toward the EKC vertex, and their distance is now less than 0.5. Moreover, several countries like Germany and USA are on their way to being close to this vertex. Additionally, by analyzing the table, countries' recent trends could be monitored. For instance, although France and the United Kingdom occupy positions near the vertex, France's distance from the vertex has recently increased while France's has recently decreased.

Chapter 4:
CONCLUSION

This study examined the dynamic interaction between economic growth and carbon dioxide emissions. Moreover, the existence of the Environmental Kuznets Curve case for CO_2 was analyzed and explained in detail. For this purpose, a new methodology in Chebyshev space was introduced to provide space for numerical analysis and clustering of patterns. The results demonstrated that only seven countries from thirty countries show the EKC pattern, while for five of them, the pattern was so weak and volatile that their behavior should be monitored for future conclusions. In addition, a reliable EKC pattern is proved only for two countries among nineteen that have exceeded the income boundaries. Therefore, in the case of CO_2 emission, there are not sufficient shreds of evidence to support the presence of EKC. Since CO_2 is the main contributor to global warming, finding an alternative solution for the current pattern sounds essential. One recommendation that could be helpful regarding this issue is to examine the growth strategies of Poland and Mexico since they have had consistent growth paths without increasing trends in their emission amount. The results could be helpful for other countries, especially developing ones with similar profiles.

The methodology introduced in this study has the potential to be applied in higher dimensions. Analyzing and organizing data in high-dimensional spaces is problematic since the issues known as the curse of dimensionality occur when the feature number increase. However, this methodology is designed and introduced in a structure to solve this problem. In the later studies, it will be shown in detail how in higher dimensions, we could deploy a unit hyper-cube environment to manage the curse of dimensionality problem.

In other words, the method section discussed in this study will be extended for higher dimensions in hyper-cube space. Afterward, there will be a possibility to include more than three features in the hyper-cube space to examine and analyze their interactions and mutual effects. In the context of EKC, features like offshore production and energy prices could be explanatory and make countries’ dynamics more visible.

Chapter 5: **APPENDIX**

5.1 Supplementary Material

This chapter entails the supplementary tables and the codes to reproduce the results. The below table is the calculation of Chebyshev distances in a three-dimensional feature space for all countries in every 50 years.

Raw Data				Relative Cube								Absolute Cube							
Country	**Year**	**GDP per capita**	**Annual CO2 per capita**	**Vrtx 0**	**Vrtx 1**	**Vrtx 2**	**Vrtx 3**	**Vrtx 4**	**Vrtx 5**	**Vrtx 6**	**Vrtx 7**	**Vrtx 0**	**Vrtx 1**	**Vrtx 2**	**Vrtx 3**	**Vrtx 4**	**Vrtx 5**	**Vrtx 6**	**Vrtx 7**
United Kingdom	1750	2702	1.007	0.015	1.000	0.985	1.000	0.990	1.000	0.990	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Germany	1800	1572	0.044	0.187	0.813	0.992	0.992	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Poland	1800	902	0.045	0.187	0.813	0.996	0.996	1.000	1.000	1.000	1.000	0.009	1.000	0.991	1.000	0.999	1.000	0.999	1.000
United Kingdom	1800	3343	2.478	0.187	0.813	0.980	0.980	0.975	0.975	0.980	0.980	0.187	0.813	0.982	0.982	0.864	0.864	0.982	0.982
United States	1800	2545	0.042	0.187	0.813	0.986	0.986	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Austria	1850	2630	0.589	0.373	0.627	0.985	0.985	0.994	0.994	0.994	0.994	0.152	0.848	0.983	0.983	0.948	0.948	0.983	0.983
Belgium	1850	2944	2.100	0.373	0.627	0.983	0.983	0.979	0.979	0.983	0.983	0.023	0.977	0.993	0.993	0.983	0.983	0.993	0.993
Canada	1850	2120	0.024	0.373	0.627	0.988	0.988	1.000	1.000	1.000	1.000	0.152	0.848	0.984	0.984	0.999	0.999	0.999	0.999
Denmark	1850	2817	0.227	0.373	0.627	0.984	0.984	0.998	0.998	0.998	0.998	0.040	0.960	0.989	0.989	0.991	0.991	0.991	0.991
France	1850	2546	0.540	0.373	0.627	0.986	0.986	0.995	0.995	0.995	0.995	0.152	0.848	0.980	0.980	0.956	0.956	0.980	0.980
Germany	1850	2276	0.449	0.373	0.627	0.987	0.987	0.996	0.996	0.996	0.996	0.229	0.771	0.984	0.984	0.972	0.972	0.984	0.984
Netherlands	1850	3779	1.013	0.373	0.627	0.978	0.978	0.990	0.990	0.990	0.990	0.023	0.977	0.994	0.994	0.995	0.995	0.995	0.995

Norway	1850	1623	0.100	0.373	0.627	0.991	0.991	0.999	0.999	0.999	0.999	0.106	0.894	0.997	0.997	0.990	0.990	0.997	0.997
Poland	1850	985	0.246	0.373	0.627	0.996	0.996	0.998	0.998	0.998	0.998	0.229	0.771	0.988	0.988	0.984	0.984	0.988	0.988
Spain	1850	1706	0.033	0.373	0.627	0.991	0.991	1.000	1.000	1.000	1.000	0.082	0.918	0.999	0.999	0.996	0.996	0.999	0.999
Sweden	1850	1715	0.058	0.373	0.627	0.991	0.991	0.999	0.999	0.999	0.999	0.087	0.913	0.995	0.995	0.996	0.996	0.996	0.996
United Kingdom	1850	4332	4.499	0.373	0.627	0.974	0.974	0.955	0.955	0.974	0.974	0.373	0.627	0.954	0.954	0.678	0.678	0.954	0.954
United States	1850	3632	0.839	0.373	0.627	0.979	0.979	0.992	0.992	0.992	0.992	0.229	0.771	0.979	0.979	0.964	0.964	0.979	0.979
World	1850	1225	0.154	0.373	0.627	0.994	0.994	0.998	0.998	0.998	0.998	0.152	0.848	0.991	0.991	0.977	0.977	0.991	0.991
Argentina	1900	4583	0.442	0.560	0.440	0.973	0.973	0.996	0.996	0.996	0.996	0.099	0.901	0.942	0.942	0.961	0.961	0.961	0.961
Australia	1900	6397	2.753	0.560	0.440	0.961	0.961	0.973	0.973	0.973	0.973	0.253	0.747	0.955	0.955	0.867	0.867	0.955	0.955
Austria	1900	4594	4.632	0.560	0.440	0.972	0.972	0.954	0.954	0.972	0.972	0.478	0.596	0.935	0.935	0.522	0.596	0.935	0.935
Belgium	1900	5947	7.393	0.560	0.440	0.964	0.964	0.927	0.927	0.964	0.964	0.445	0.686	0.912	0.912	0.555	0.686	0.912	0.912
Canada	1900	4640	3.812	0.560	0.440	0.972	0.972	0.962	0.962	0.972	0.972	0.404	0.596	0.926	0.926	0.794	0.794	0.926	0.926
Chile	1900	3386	0.271	0.560	0.440	0.980	0.980	0.997	0.997	0.997	0.997	0.041	0.959	0.977	0.977	0.979	0.979	0.979	0.979
Denmark	1900	4809	2.007	0.560	0.440	0.971	0.971	0.980	0.980	0.980	0.980	0.326	0.674	0.944	0.944	0.865	0.865	0.944	0.944
Finland	1900	2659	0.228	0.560	0.440	0.985	0.985	0.998	0.998	0.998	0.998	0.253	0.747	0.968	0.968	0.985	0.985	0.985	0.985
France	1900	4584	3.231	0.560	0.440	0.973	0.973	0.968	0.968	0.973	0.973	0.404	0.596	0.924	0.924	0.694	0.694	0.924	0.924
Germany	1900	4758	5.921	0.560	0.440	0.971	0.971	0.941	0.941	0.971	0.971	0.459	0.541	0.929	0.929	0.586	0.586	0.929	0.929
Greece	1900	1972	0.084	0.560	0.440	0.989	0.989	0.999	0.999	0.999	0.999	0.219	0.781	0.978	0.978	0.992	0.992	0.992	0.992
Hungary	1900	2681	1.349	0.560	0.440	0.985	0.985	0.987	0.987	0.987	0.987	0.203	0.797	0.961	0.961	0.879	0.879	0.961	0.961
India	1900	955	0.041	0.560	0.440	0.996	0.996	1.000	1.000	1.000	1.000	0.248	0.752	0.981	0.981	0.980	0.980	0.981	0.981
Indonesia	1900	1151	0.032	0.560	0.440	0.995	0.995	1.000	1.000	1.000	1.000	0.085	0.915	0.989	0.989	0.986	0.986	0.989	0.989
Italy	1900	3264	0.416	0.560	0.440	0.981	0.981	0.996	0.996	0.996	0.996	0.253	0.747	0.979	0.979	0.952	0.952	0.979	0.979
Japan	1900	2123	0.443	0.560	0.440	0.988	0.988	0.996	0.996	0.996	0.996	0.203	0.797	0.985	0.985	0.957	0.957	0.985	0.985
Malaysia	1900	818	0.028	0.560	0.440	0.997	0.997	1.000	1.000	1.000	1.000	0.002	1.000	0.999	1.000	0.998	1.000	0.999	1.000
Mexico	1900	1822	0.075	0.560	0.440	0.990	0.990	0.999	0.999	0.999	0.999	0.041	0.959	0.996	0.996	0.994	0.994	0.996	0.996
Netherlands	1900	5306	2.858	0.560	0.440	0.968	0.968	0.972	0.972	0.972	0.972	0.314	0.686	0.959	0.959	0.846	0.846	0.959	0.959

New Zealand	1900	6851	3.020	0.560	0.440	0.958	0.958	0.970	0.970	0.970	0.970	0.271	0.843	0.957	0.957	0.729	0.843	0.957	0.957
Norway	1900	3249	1.868	0.560	0.440	0.981	0.981	0.982	0.982	0.982	0.982	0.372	0.628	0.977	0.977	0.807	0.807	0.977	0.977
Peru	1900	1084	0.067	0.560	0.440	0.995	0.995	0.999	0.999	0.999	0.999	0.119	0.881	0.975	0.975	0.967	0.967	0.975	0.975
Poland	1900	2700	2.601	0.560	0.440	0.985	0.985	0.974	0.974	0.985	0.985	0.459	0.541	0.924	0.924	0.803	0.803	0.924	0.924
Portugal	1900	2075	0.456	0.560	0.440	0.989	0.989	0.995	0.995	0.995	0.995	0.203	0.797	0.977	0.977	0.933	0.933	0.977	0.977
Romania	1900	615	0.113	0.560	0.440	0.998	0.998	0.999	0.999	0.999	0.999	0.244	0.756	0.984	0.984	0.988	0.988	0.988	0.988
South Africa	1900	1494	0.437	0.560	0.440	0.992	0.992	0.996	0.996	0.996	0.996	0.119	0.881	0.974	0.974	0.957	0.957	0.974	0.974
Spain	1900	2676	0.603	0.560	0.440	0.985	0.985	0.994	0.994	0.994	0.994	0.355	0.645	0.968	0.968	0.928	0.928	0.968	0.968
Sweden	1900	3320	1.791	0.560	0.440	0.981	0.981	0.982	0.982	0.982	0.982	0.359	0.641	0.958	0.958	0.845	0.845	0.958	0.958
Switzerland	1900	6612	1.728	0.560	0.440	0.960	0.960	0.983	0.983	0.983	0.983	0.263	0.738	0.934	0.934	0.771	0.771	0.934	0.934
United Kingdom	1900	7594	10.131	0.560	0.440	0.953	0.953	0.900	0.900	0.953	0.953	0.842	0.842	0.862	0.862	0.560	0.440	0.862	0.862
United States	1900	8038	8.414	0.560	0.440	0.950	0.950	0.917	0.917	0.950	0.950	0.459	0.541	0.896	0.896	0.623	0.623	0.896	0.896
World	1900	2212	1.185	0.560	0.440	0.988	0.988	0.988	0.988	0.988	0.988	0.404	0.596	0.921	0.921	0.761	0.761	0.921	0.921
Afghanistan	1950	1156	0.011	0.746	0.254	0.994	0.994	1.000	1.000	1.000	1.000	0.456	1.000	0.544	1.000	1.000	1.000	1.000	1.000
Albania	1950	1596	0.235	0.746	0.254	0.992	0.992	0.998	0.998	0.998	0.998	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Algeria	1950	2176	0.427	0.746	0.254	0.988	0.988	0.996	0.996	0.996	0.996	0.002	1.000	0.998	1.000	0.999	1.000	0.999	1.000
Angola	1950	1677	0.041	0.746	0.254	0.991	0.991	1.000	1.000	1.000	1.000	0.078	1.000	0.922	1.000	1.000	1.000	1.000	1.000
Argentina	1950	7949	1.756	0.746	0.254	0.951	0.951	0.983	0.983	0.983	0.983	0.481	0.519	0.736	0.736	0.664	0.664	0.736	0.736
Australia	1950	11815	6.694	0.746	0.254	0.926	0.926	0.934	0.934	0.934	0.934	0.570	0.430	0.836	0.836	0.662	0.662	0.836	0.836
Austria	1950	5907	3.012	0.746	0.254	0.964	0.964	0.970	0.970	0.970	0.970	0.657	0.343	0.903	0.903	0.693	0.693	0.903	0.903
Bahrain	1950	3354	11.948	0.746	0.254	0.980	0.980	0.882	0.882	0.980	0.980	0.323	1.000	1.000	1.000	0.677	1.000	1.000	1.000
Bangladesh	1950	861	0.026	0.746	0.254	0.996	0.996	1.000	1.000	1.000	1.000	0.021	1.000	0.979	1.000	1.000	1.000	1.000	1.000
Barbados	1950	3390	0.347	0.746	0.254	0.980	0.980	0.997	0.997	0.997	0.997	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Belgium	1950	8706	8.822	0.746	0.254	0.946	0.946	0.913	0.913	0.946	0.946	0.605	0.560	0.838	0.838	0.605	0.440	0.838	0.838
Bolivia	1950	3011	0.161	0.746	0.254	0.983	0.983	0.998	0.998	0.998	0.998	0.244	0.756	0.765	0.765	0.924	0.924	0.924	0.924
Brazil	1950	2236	0.364	0.746	0.254	0.988	0.988	0.996	0.996	0.996	0.996	0.419	0.581	0.912	0.912	0.896	0.896	0.912	0.912

Bulgaria	1950	2632	1.034	0.746	0.254	0.985	0.985	0.990	0.990	0.990	0.990	0.460	0.540	0.937	0.937	0.900	0.900	0.937	0.937
Burundi	1950	595	0.004	0.746	0.254	0.998	0.998	1.000	1.000	1.000	1.000	0.022	1.000	1.000	1.000	0.978	1.000	1.000	1.000
Cameroon	1950	1070	0.032	0.746	0.254	0.995	0.995	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Canada	1950	11622	11.223	0.746	0.254	0.927	0.927	0.889	0.889	0.927	0.927	0.657	0.606	0.766	0.766	0.657	0.394	0.766	0.766
Cape Verde	1950	1006	0.576	0.746	0.254	0.995	0.995	0.994	0.994	0.995	0.995	0.436	1.000	1.000	1.000	0.564	1.000	1.000	1.000
Chile	1950	5880	1.281	0.746	0.254	0.964	0.964	0.987	0.987	0.987	0.987	0.447	0.553	0.847	0.847	0.754	0.754	0.847	0.847
China	1950	799	0.142	0.746	0.254	0.997	0.997	0.999	0.999	0.999	0.999	0.364	0.636	1.000	1.000	0.984	0.984	1.000	1.000
Colombia	1950	3432	0.626	0.746	0.254	0.980	0.980	0.994	0.994	0.994	0.994	0.322	0.701	0.859	0.859	0.678	0.701	0.859	0.859
Costa Rica	1950	3129	0.302	0.746	0.254	0.982	0.982	0.997	0.997	0.997	0.997	0.002	1.000	0.998	1.000	0.999	1.000	0.999	1.000
Cuba	1950	2638	0.947	0.746	0.254	0.985	0.985	0.991	0.991	0.991	0.991	0.269	0.883	0.909	0.909	0.731	0.883	0.909	0.909
Cyprus	1950	2885	0.541	0.746	0.254	0.983	0.983	0.995	0.995	0.995	0.995	0.004	1.000	0.996	1.000	1.000	1.000	1.000	1.000
Democratic Republic of Congo	1950	909	0.121	0.746	0.254	0.996	0.996	0.999	0.999	0.999	0.999	0.556	1.000	0.450	1.000	0.556	1.000	0.550	1.000
Denmark	1950	11067	5.151	0.746	0.254	0.931	0.931	0.949	0.949	0.949	0.949	0.611	0.389	0.802	0.802	0.643	0.643	0.802	0.802
Djibouti	1950	3459	0.177	0.746	0.254	0.980	0.980	0.998	0.998	0.998	0.998	0.535	1.000	0.465	1.000	1.000	1.000	1.000	1.000
Dominican Republic	1950	1637	0.147	0.746	0.254	0.991	0.991	0.999	0.999	0.999	0.999	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ecuador	1950	2970	0.213	0.746	0.254	0.983	0.983	0.998	0.998	0.998	0.998	0.327	0.673	0.855	0.855	0.926	0.926	0.926	0.926
Egypt	1950	1451	0.500	0.746	0.254	0.993	0.993	0.995	0.995	0.995	0.995	0.352	0.648	0.996	0.996	0.809	0.809	0.996	0.996
El Salvador	1950	2375	0.122	0.746	0.254	0.987	0.987	0.999	0.999	0.999	0.999	0.002	1.000	0.998	1.000	1.000	1.000	1.000	1.000
Equatorial Guinea	1950	797	0.049	0.746	0.254	0.997	0.997	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Eswatini	1950	604	0.013	0.746	0.254	0.998	0.998	1.000	1.000	1.000	1.000	0.002	1.000	1.000	1.000	0.998	1.000	1.000	1.000
Ethiopia	1950	622	0.005	0.746	0.254	0.998	0.998	1.000	1.000	1.000	1.000	0.010	1.000	1.000	1.000	0.990	1.000	1.000	1.000
Finland	1950	6779	1.633	0.746	0.254	0.958	0.958	0.984	0.984	0.984	0.984	0.570	0.430	0.861	0.861	0.884	0.884	0.884	0.884
France	1950	8266	4.839	0.746	0.254	0.949	0.949	0.952	0.952	0.952	0.952	0.657	0.463	0.824	0.824	0.657	0.537	0.824	0.824
Gambia	1950	982	0.048	0.746	0.254	0.996	0.996	1.000	1.000	1.000	1.000	0.062	1.000	1.000	1.000	0.938	1.000	1.000	1.000
Germany	1950	6186	7.299	0.746	0.254	0.962	0.962	0.928	0.928	0.962	0.962	0.688	0.511	0.897	0.897	0.688	0.489	0.897	0.897
Ghana	1950	1788	0.127	0.746	0.254	0.990	0.990	0.999	0.999	0.999	0.999	0.108	1.000	0.892	1.000	1.000	1.000	1.000	1.000

Greece	1950	3052	0.538	0.746	0.254	0.982	0.982	0.995	0.995	0.995	0.995	0.550	0.450	0.938	0.938	0.948	0.948	0.948	0.948
Guatemala	1950	3323	0.199	0.746	0.254	0.981	0.981	0.998	0.998	0.998	0.998	0.181	0.883	0.879	0.883	0.819	0.883	0.879	0.883
Guinea-Bissau	1950	462	0.014	0.746	0.254	0.999	0.999	1.000	1.000	1.000	1.000	0.030	1.000	1.000	1.000	0.970	1.000	1.000	1.000
Haiti	1950	1790	0.035	0.746	0.254	0.990	0.990	1.000	1.000	1.000	1.000	0.659	1.000	0.341	1.000	0.960	1.000	0.960	1.000
Honduras	1950	2018	0.194	0.746	0.254	0.989	0.989	0.998	0.998	0.998	0.998	0.010	1.000	0.990	1.000	1.000	1.000	1.000	1.000
Hong Kong	1950	4082	0.668	0.746	0.254	0.976	0.976	0.993	0.993	0.993	0.993	0.008	1.000	0.992	1.000	1.000	1.000	1.000	1.000
Hungary	1950	3953	1.969	0.746	0.254	0.977	0.977	0.980	0.980	0.980	0.980	0.541	0.459	0.907	0.907	0.803	0.803	0.907	0.907
Iceland	1950	8498	5.188	0.746	0.254	0.947	0.947	0.949	0.949	0.949	0.949	0.095	1.000	0.988	1.000	0.905	1.000	0.988	1.000
India	1950	987	0.163	0.746	0.254	0.996	0.996	0.998	0.998	0.998	0.998	0.567	0.433	0.976	0.976	0.916	0.916	0.976	0.976
Indonesia	1950	1280	0.141	0.746	0.254	0.994	0.994	0.999	0.999	0.999	0.999	0.473	0.527	0.977	0.977	0.938	0.938	0.977	0.977
Iran	1950	2742	4.914	0.746	0.254	0.984	0.984	0.951	0.951	0.984	0.984	0.554	0.648	0.912	0.912	0.446	0.648	0.912	0.912
Iraq	1950	2174	0.288	0.746	0.254	0.988	0.988	0.997	0.997	0.997	0.997	0.053	1.000	0.947	1.000	1.000	1.000	1.000	1.000
Ireland	1950	5504	3.339	0.746	0.254	0.967	0.967	0.967	0.967	0.967	0.967	0.352	0.648	0.976	0.976	0.734	0.734	0.976	0.976
Israel	1950	4490	1.327	0.746	0.254	0.973	0.973	0.987	0.987	0.987	0.987	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Italy	1950	5582	0.889	0.746	0.254	0.966	0.966	0.991	0.991	0.991	0.991	0.570	0.430	0.910	0.910	0.897	0.897	0.910	0.910
Jamaica	1950	2115	0.193	0.746	0.254	0.988	0.988	0.998	0.998	0.998	0.998	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Japan	1950	3062	1.238	0.746	0.254	0.982	0.982	0.988	0.988	0.988	0.988	0.541	0.459	0.960	0.960	0.879	0.879	0.960	0.960
Jordan	1950	2651	0.358	0.746	0.254	0.985	0.985	0.996	0.996	0.996	0.996	0.018	1.000	0.993	1.000	0.982	1.000	0.993	1.000
Kenya	1950	1038	0.150	0.746	0.254	0.995	0.995	0.999	0.999	0.999	0.999	0.012	1.000	0.988	1.000	1.000	1.000	1.000	1.000
Kuwait	1950	46031	2.513	0.746	0.293	0.746	0.707	0.975	0.975	0.975	0.975	0.548	1.000	0.452	1.000	0.976	1.000	0.976	1.000
Lebanon	1950	3872	1.133	0.746	0.254	0.977	0.977	0.989	0.989	0.989	0.989	0.103	1.000	0.897	1.000	0.919	1.000	0.919	1.000
Liberia	1950	3151	0.051	0.746	0.254	0.982	0.982	0.999	0.999	0.999	0.999	0.654	1.000	0.346	1.000	0.995	1.000	0.995	1.000
Libya	1950	620	0.127	0.746	0.254	0.998	0.998	0.999	0.999	0.999	0.999	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Luxembourg	1950	13378	25.064	0.746	0.254	0.916	0.916	0.752	0.752	0.916	0.916	0.370	1.000	0.977	1.000	0.630	1.000	0.977	1.000
Madagascar	1950	1516	0.075	0.746	0.254	0.992	0.992	0.999	0.999	0.999	0.999	0.463	1.000	0.537	1.000	0.901	1.000	0.901	1.000
Malawi	1950	516	0.079	0.746	0.254	0.999	0.999	0.999	0.999	0.999	0.999	0.244	1.000	1.000	1.000	0.756	1.000	1.000	1.000
Malaysia	1950	2485	0.598	0.746	0.254	0.986	0.986	0.994	0.994	0.994	0.994	0.424	0.576	0.930	0.930	0.931	0.931	0.931	0.931

Malta	1950	1573	0.787	0.746	0.254	0.992	0.992	0.992	0.992	0.992	0.992	0.007	1.000	1.000	1.000	0.993	1.000	1.000	1.000
Mauritius	1950	3942	0.409	0.746	0.254	0.977	0.977	0.996	0.996	0.996	0.996	0.055	1.000	1.000	1.000	0.945	1.000	1.000	1.000
Mexico	1950	3510	1.092	0.746	0.254	0.979	0.979	0.989	0.989	0.989	0.989	0.447	0.553	0.881	0.881	0.825	0.825	0.881	0.881
Mongolia	1950	677	0.366	0.746	0.254	0.998	0.998	0.996	0.996	0.998	0.998	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Morocco	1950	2319	0.285	0.746	0.254	0.987	0.987	0.997	0.997	0.997	0.997	0.033	1.000	0.968	1.000	0.967	1.000	0.968	1.000
Mozambique	1950	1806	0.151	0.746	0.254	0.990	0.990	0.999	0.999	0.999	0.999	0.427	1.000	0.573	1.000	0.738	1.000	0.738	1.000
Myanmar	1950	631	0.045	0.746	0.254	0.998	0.998	1.000	1.000	1.000	1.000	0.218	0.782	1.000	1.000	1.000	1.000	1.000	1.000
Nepal	1950	802	0.003	0.746	0.254	0.997	0.997	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Netherlands	1950	9558	5.107	0.746	0.254	0.941	0.941	0.949	0.949	0.949	0.949	0.605	0.395	0.863	0.863	0.663	0.663	0.863	0.863
New Zealand	1950	13479	4.491	0.746	0.254	0.915	0.915	0.956	0.956	0.956	0.956	0.514	0.486	0.734	0.734	0.552	0.552	0.734	0.734
Nicaragua	1950	2565	0.147	0.746	0.254	0.985	0.985	0.999	0.999	0.999	0.999	0.152	0.907	0.856	0.907	0.848	0.907	0.856	0.907
Nigeria	1950	1200	0.060	0.746	0.254	0.994	0.994	0.999	0.999	0.999	0.999	0.019	1.000	0.981	1.000	0.984	1.000	0.984	1.000
Norway	1950	8655	2.582	0.746	0.254	0.946	0.946	0.974	0.974	0.974	0.974	0.638	0.362	0.912	0.912	0.734	0.734	0.912	0.912
Pakistan	1950	1025	0.143	0.746	0.254	0.995	0.995	0.999	0.999	0.999	0.999	0.016	1.000	0.984	1.000	1.000	1.000	1.000	1.000
Panama	1950	2577	0.609	0.746	0.254	0.985	0.985	0.994	0.994	0.994	0.994	0.211	0.971	0.996	0.996	0.789	0.971	0.996	0.996
Paraguay	1950	2391	0.042	0.746	0.254	0.987	0.987	1.000	1.000	1.000	1.000	0.019	1.000	0.981	1.000	0.991	1.000	0.991	1.000
Peru	1950	3679	0.584	0.746	0.254	0.978	0.978	0.994	0.994	0.994	0.994	0.493	0.507	0.749	0.749	0.704	0.704	0.749	0.749
Philippines	1950	1706	0.194	0.746	0.254	0.991	0.991	0.998	0.998	0.998	0.998	0.387	0.613	0.905	0.905	0.853	0.853	0.905	0.905
Poland	1950	3900	4.517	0.746	0.254	0.977	0.977	0.955	0.955	0.977	0.977	0.688	0.345	0.879	0.879	0.688	0.655	0.879	0.879
Portugal	1950	3325	0.668	0.746	0.254	0.981	0.981	0.993	0.993	0.993	0.993	0.541	0.459	0.928	0.928	0.901	0.901	0.928	0.928
Qatar	1950	48436	14.066	0.746	0.309	0.746	0.691	0.861	0.861	0.861	0.861	0.254	1.000	0.746	1.000	0.886	1.000	0.886	1.000
Romania	1950	824	1.196	0.746	0.254	0.997	0.997	0.988	0.988	0.997	0.997	0.564	0.436	0.973	0.973	0.869	0.869	0.973	0.973
Rwanda	1950	1020	0.008	0.746	0.254	0.995	0.995	1.000	1.000	1.000	1.000	0.256	1.000	0.744	1.000	0.976	1.000	0.976	1.000
Saint Lucia	1950	1231	0.044	0.746	0.254	0.994	0.994	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Saudi Arabia	1950	3556	1.647	0.746	0.254	0.979	0.979	0.984	0.984	0.984	0.984	0.071	1.000	1.000	1.000	0.929	1.000	1.000	1.000
Sierra Leone	1950	902	0.077	0.746	0.254	0.996	0.996	0.999	0.999	0.999	0.999	0.094	1.000	0.926	1.000	0.906	1.000	0.926	1.000

Singapore	1950	3572	1.873	0.746	0.254	0.979	0.979	0.981	0.981	0.981	0.981	0.091	1.000	0.981	1.000	0.909	1.000	0.981	1.000
South Africa	1950	4041	4.478	0.746	0.254	0.976	0.976	0.956	0.956	0.976	0.976	0.493	0.507	0.743	0.743	0.550	0.550	0.743	0.743
South Korea	1950	998	0.114	0.746	0.254	0.995	0.995	0.999	0.999	0.999	0.999	0.364	0.636	0.998	0.998	0.991	0.991	0.998	0.998
Spain	1950	3464	1.177	0.746	0.254	0.980	0.980	0.988	0.988	0.988	0.988	0.628	0.372	0.943	0.943	0.860	0.860	0.943	0.943
Sri Lanka	1950	1997	0.204	0.746	0.254	0.989	0.989	0.998	0.998	0.998	0.998	0.049	1.000	1.000	1.000	0.951	1.000	1.000	1.000
Sudan	1950	1309	0.088	0.746	0.254	0.994	0.994	0.999	0.999	0.999	0.999	0.039	1.000	0.961	1.000	1.000	1.000	1.000	1.000
Sweden	1950	10742	4.088	0.746	0.254	0.933	0.933	0.960	0.960	0.960	0.960	0.630	0.370	0.790	0.790	0.644	0.644	0.790	0.790
Switzerland	1950	11541	2.192	0.746	0.254	0.928	0.928	0.978	0.978	0.978	0.978	0.575	0.425	0.850	0.850	0.707	0.707	0.850	0.850
Syria	1950	3838	0.121	0.746	0.254	0.977	0.977	0.999	0.999	0.999	0.999	0.099	1.000	0.901	1.000	0.996	1.000	0.996	1.000
Taiwan	1950	1460	0.498	0.746	0.254	0.993	0.993	0.995	0.995	0.995	0.995	0.419	0.581	0.989	0.989	0.964	0.964	0.989	0.989
Tanzania	1950	676	0.065	0.746	0.254	0.998	0.998	0.999	0.999	0.999	0.999	0.052	1.000	1.000	1.000	0.948	1.000	1.000	1.000
Thailand	1950	1302	0.046	0.746	0.254	0.994	0.994	1.000	1.000	1.000	1.000	0.150	0.850	1.000	1.000	0.990	0.990	1.000	1.000
Togo	1950	870	0.018	0.746	0.254	0.996	0.996	1.000	1.000	1.000	1.000	0.001	1.000	1.000	1.000	0.999	1.000	1.000	1.000
Trinidad and Tobago	1950	5856	3.643	0.746	0.254	0.964	0.964	0.964	0.964	0.964	0.964	0.053	1.000	1.000	1.000	0.947	1.000	1.000	1.000
Tunisia	1950	1777	0.338	0.746	0.254	0.991	0.991	0.997	0.997	0.997	0.997	0.001	1.000	0.999	1.000	1.000	1.000	1.000	1.000
Turkey	1950	2079	0.443	0.746	0.254	0.989	0.989	0.996	0.996	0.996	0.996	0.541	0.459	0.934	0.934	0.918	0.918	0.934	0.934
Uganda	1950	1095	0.021	0.746	0.254	0.995	0.995	1.000	1.000	1.000	1.000	0.200	1.000	0.800	1.000	1.000	1.000	1.000	1.000
United Kingdom	1950	11061	9.894	0.746	0.254	0.931	0.931	0.902	0.902	0.931	0.931	0.820	0.820	0.820	0.820	0.746	0.254	0.764	0.764
United States	1950	15240	16.003	0.746	0.254	0.904	0.904	0.842	0.842	0.904	0.904	0.719	0.719	0.759	0.759	0.688	0.312	0.759	0.759
Uruguay	1950	7015	1.096	0.746	0.254	0.957	0.957	0.989	0.989	0.989	0.989	0.425	0.791	0.819	0.819	0.575	0.791	0.819	0.819
Venezuela	1950	8462	6.982	0.746	0.254	0.948	0.948	0.931	0.931	0.948	0.948	0.424	0.596	0.657	0.657	0.576	0.596	0.657	0.657
Vietnam	1950	1049	0.060	0.746	0.254	0.995	0.995	0.999	0.999	0.999	0.999	0.352	0.648	1.000	1.000	0.996	0.996	1.000	1.000
World	1950	3351	2.367	0.746	0.254	0.980	0.980	0.977	0.977	0.980	0.980	0.657	0.488	0.841	0.841	0.657	0.512	0.841	0.841
Yemen	1950	1452	0.013	0.746	0.254	0.993	0.993	1.000	1.000	1.000	1.000	0.002	1.000	1.000	1.000	0.998	1.000	1.000	1.000
Zambia	1950	1054	1.009	0.746	0.254	0.995	0.995	0.990	0.990	0.995	0.995	0.572	1.000	1.000	1.000	0.428	1.000	1.000	1.000
Zimbabwe	1950	1117	1.158	0.746	0.254	0.995	0.995	0.989	0.989	0.995	0.995	0.517	1.000	1.000	1.000	0.483	1.000	1.000	1.000

Afghanistan	2000	502	0.037	0.933	0.067	0.999	0.999	1.000	1.000	1.000	1.000	0.735	0.265	0.954	0.954	0.935	0.935	0.954	0.954
Albania	2000	4808	0.960	0.933	0.067	0.971	0.971	0.990	0.990	0.990	0.990	0.735	0.338	0.735	0.662	0.735	0.726	0.735	0.726
Algeria	2000	6835	2.649	0.933	0.067	0.958	0.958	0.974	0.974	0.974	0.974	0.735	0.654	0.735	0.654	0.735	0.385	0.735	0.615
Angola	2000	2014	0.580	0.933	0.067	0.989	0.989	0.994	0.994	0.994	0.994	0.735	0.413	0.877	0.877	0.735	0.587	0.877	0.877
Argentina	2000	14369	3.861	0.933	0.090	0.933	0.910	0.962	0.962	0.962	0.962	0.863	0.812	0.863	0.812	0.863	0.656	0.863	0.344
Armenia	2000	5140	1.137	0.933	0.067	0.969	0.969	0.989	0.989	0.989	0.989	0.600	0.400	0.862	0.862	0.807	0.807	0.862	0.862
Australia	2000	36603	18.525	0.933	0.233	0.933	0.767	0.933	0.817	0.933	0.817	0.952	0.952	0.952	0.952	0.886	0.709	0.886	0.291
Austria	2000	34796	8.196	0.933	0.221	0.933	0.779	0.933	0.919	0.933	0.919	0.909	0.854	0.909	0.854	0.909	0.800	0.909	0.200
Azerbaijan	2000	4215	3.633	0.933	0.067	0.975	0.975	0.964	0.964	0.975	0.975	0.600	0.400	0.916	0.916	0.946	0.946	0.946	0.946
Bahrain	2000	17022	28.278	0.933	0.280	0.933	0.893	0.933	0.720	0.933	0.893	0.938	0.938	0.938	0.938	0.735	0.362	0.735	0.638
Bangladesh	2000	1485	0.208	0.933	0.067	0.992	0.992	0.998	0.998	0.998	0.998	0.735	0.374	0.790	0.790	0.735	0.626	0.790	0.790
Barbados	2000	12600	4.241	0.933	0.079	0.933	0.921	0.958	0.958	0.958	0.958	0.911	0.911	0.735	0.720	0.911	0.911	0.735	0.280
Belarus	2000	9111	5.542	0.933	0.067	0.943	0.943	0.945	0.945	0.945	0.945	0.600	0.400	0.821	0.821	0.999	0.999	0.999	0.999
Belgium	2000	33720	12.324	0.933	0.214	0.933	0.786	0.933	0.878	0.933	0.878	0.895	0.843	0.895	0.843	0.895	0.837	0.895	0.163
Benin	2000	1909	0.215	0.933	0.067	0.990	0.990	0.998	0.998	0.998	0.998	0.700	0.621	0.700	0.379	0.708	0.708	0.708	0.708
Bolivia	2000	4174	1.026	0.933	0.067	0.975	0.975	0.990	0.990	0.990	0.990	0.800	0.487	0.800	0.524	0.800	0.513	0.800	0.524
Bosnia and Herzegovina	2000	7082	3.653	0.933	0.067	0.956	0.956	0.964	0.964	0.964	0.964	0.727	0.608	0.727	0.487	0.727	0.608	0.727	0.513
Botswana	2000	8044	2.299	0.933	0.067	0.950	0.950	0.977	0.977	0.977	0.977	0.682	0.682	0.682	0.682	0.609	0.462	0.609	0.538
Brazil	2000	9834	1.946	0.933	0.067	0.939	0.939	0.981	0.981	0.981	0.981	0.846	0.698	0.846	0.698	0.846	0.598	0.846	0.402
Bulgaria	2000	8411	5.685	0.933	0.067	0.948	0.948	0.944	0.944	0.948	0.948	0.857	0.558	0.857	0.595	0.857	0.442	0.857	0.595
Burkina Faso	2000	1275	0.089	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.700	0.524	0.700	0.476	0.700	0.595	0.700	0.595
Burundi	2000	740	0.043	0.933	0.067	0.997	0.997	1.000	1.000	1.000	1.000	0.735	0.686	0.739	0.739	0.735	0.314	0.739	0.739
Cambodia	2000	1659	0.163	0.933	0.067	0.991	0.991	0.998	0.998	0.998	0.998	0.714	0.297	0.714	0.703	0.802	0.802	0.802	0.802
Cameroon	2000	1961	0.216	0.933	0.067	0.989	0.989	0.998	0.998	0.998	0.998	0.735	0.490	0.735	0.510	0.735	0.722	0.735	0.722
Canada	2000	36943	18.522	0.933	0.235	0.933	0.765	0.933	0.817	0.933	0.817	1.000	1.000	1.000	1.000	0.909	0.817	0.909	0.183
Cape Verde	2000	3584	0.505	0.933	0.067	0.979	0.979	0.995	0.995	0.995	0.995	0.735	0.443	0.735	0.557	0.735	0.625	0.735	0.625

Central African Republic	2000	964	0.064	0.933	0.067	0.996	0.996	0.999	0.999	0.999	0.999	0.695	0.427	0.695	0.611	0.695	0.573	0.695	0.611
Chad	2000	716	0.058	0.933	0.067	0.997	0.997	0.999	0.999	0.999	0.999	0.695	0.591	0.895	0.895	0.695	0.409	0.895	0.895
Chile	2000	15212	3.787	0.933	0.096	0.933	0.904	0.962	0.962	0.962	0.962	0.854	0.806	0.854	0.806	0.854	0.640	0.854	0.360
China	2000	4730	2.665	0.933	0.067	0.972	0.972	0.974	0.974	0.974	0.974	0.832	0.368	0.832	0.680	0.832	0.632	0.832	0.680
Colombia	2000	8497	1.420	0.933	0.067	0.947	0.947	0.986	0.986	0.986	0.986	0.814	0.733	0.814	0.733	0.814	0.571	0.814	0.429
Comoros	2000	1204	0.189	0.933	0.067	0.994	0.994	0.998	0.998	0.998	0.998	0.695	0.521	0.695	0.479	0.695	0.546	0.695	0.546
Congo	2000	4159	0.181	0.933	0.067	0.975	0.975	0.998	0.998	0.998	0.998	0.695	0.502	0.695	0.498	0.937	0.937	0.937	0.937
Costa Rica	2000	9320	1.361	0.933	0.067	0.942	0.942	0.987	0.987	0.987	0.987	0.735	0.704	0.735	0.704	0.735	0.536	0.735	0.464
Cote d'Ivoire	2000	2353	0.393	0.933	0.067	0.987	0.987	0.996	0.996	0.996	0.996	0.700	0.394	0.742	0.742	0.700	0.606	0.742	0.742
Croatia	2000	13245	4.440	0.933	0.083	0.933	0.917	0.956	0.956	0.956	0.956	0.749	0.749	0.749	0.749	0.727	0.545	0.727	0.455
Cuba	2000	4009	2.317	0.933	0.067	0.976	0.976	0.977	0.977	0.977	0.977	0.766	0.665	0.766	0.690	0.766	0.335	0.766	0.690
Cyprus	2000	22327	7.548	0.933	0.141	0.933	0.859	0.933	0.925	0.933	0.925	0.932	0.932	0.932	0.932	0.753	0.753	0.735	0.265
Czechia	2000	17056	12.355	0.933	0.122	0.933	0.893	0.933	0.878	0.933	0.893	0.625	0.378	0.625	0.622	0.690	0.690	0.690	0.690
Democratic Republic of Congo	2000	414	0.019	0.933	0.067	0.999	0.999	1.000	1.000	1.000	1.000	0.735	0.265	0.989	0.989	0.987	0.987	0.989	0.989
Denmark	2000	39021	10.165	0.933	0.248	0.933	0.752	0.933	0.899	0.933	0.899	0.897	0.834	0.897	0.712	0.897	0.834	0.897	0.288
Djibouti	2000	1881	0.511	0.933	0.067	0.990	0.990	0.995	0.995	0.995	0.995	0.735	0.349	0.981	0.981	0.735	0.651	0.981	0.981
Dominica	2000	5697	1.473	0.933	0.067	0.965	0.965	0.985	0.985	0.985	0.985	0.731	0.558	0.731	0.558	0.731	0.546	0.731	0.454
Dominican Republic	2000	6788	2.242	0.933	0.067	0.958	0.958	0.978	0.978	0.978	0.978	0.922	0.922	0.922	0.922	0.735	0.361	0.735	0.639
Ecuador	2000	6908	1.622	0.933	0.067	0.958	0.958	0.984	0.984	0.984	0.984	0.822	0.597	0.822	0.597	0.822	0.563	0.822	0.437
Egypt	2000	6594	2.039	0.933	0.067	0.960	0.960	0.980	0.980	0.980	0.980	0.829	0.784	0.829	0.784	0.829	0.491	0.829	0.509
El Salvador	2000	5404	0.963	0.933	0.067	0.967	0.967	0.990	0.990	0.990	0.990	0.842	0.842	0.842	0.842	0.735	0.488	0.735	0.512
Equatorial Guinea	2000	12915	1.016	0.933	0.081	0.933	0.919	0.990	0.990	0.990	0.990	0.735	0.265	0.741	0.741	0.930	0.930	0.930	0.930
Estonia	2000	16807	11.068	0.933	0.110	0.933	0.894	0.933	0.890	0.933	0.894	0.890	0.586	0.890	0.435	0.890	0.586	0.890	0.565
Eswatini	2000	4895	1.203	0.933	0.067	0.971	0.971	0.988	0.988	0.988	0.988	0.933	0.933	0.933	0.933	0.735	0.575	0.735	0.425
Ethiopia	2000	772	0.052	0.933	0.067	0.997	0.997	0.999	0.999	0.999	0.999	0.735	0.338	0.877	0.877	0.735	0.662	0.877	0.877

Finland	2000	32690	10.994	0.933	0.208	0.933	0.792	0.933	0.891	0.933	0.891	0.886	0.808	0.886	0.791	0.886	0.808	0.886	0.209
France	2000	33410	6.878	0.933	0.212	0.933	0.788	0.933	0.932	0.933	0.932	0.909	0.861	0.909	0.662	0.909	0.861	0.909	0.338
Gabon	2000	10638	3.801	0.933	0.067	0.934	0.934	0.962	0.962	0.962	0.962	0.695	0.466	0.695	0.534	0.695	0.654	0.695	0.654
Gambia	2000	1441	0.209	0.933	0.067	0.993	0.993	0.998	0.998	0.998	0.998	0.795	0.795	0.795	0.795	0.735	0.510	0.735	0.490
Georgia	2000	4892	1.032	0.933	0.067	0.971	0.971	0.990	0.990	0.990	0.990	0.600	0.400	0.873	0.873	0.778	0.778	0.873	0.873
Germany	2000	33367	11.055	0.933	0.212	0.933	0.788	0.933	0.891	0.933	0.891	0.917	0.775	0.917	0.775	0.917	0.713	0.917	0.287
Ghana	2000	2100	0.317	0.933	0.067	0.988	0.988	0.997	0.997	0.997	0.997	0.735	0.418	0.779	0.779	0.735	0.582	0.779	0.779
Greece	2000	20965	9.294	0.933	0.132	0.933	0.868	0.933	0.908	0.933	0.908	0.902	0.902	0.902	0.902	0.881	0.712	0.881	0.288
Guatemala	2000	5860	0.838	0.933	0.067	0.964	0.964	0.992	0.992	0.992	0.992	0.774	0.774	0.774	0.774	0.766	0.668	0.766	0.332
Guinea	2000	1047	0.181	0.933	0.067	0.995	0.995	0.998	0.998	0.998	0.998	0.700	0.538	0.700	0.573	0.700	0.462	0.700	0.573
Guinea-Bissau	2000	1231	0.122	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.739	0.739	0.735	0.490	0.739	0.739	0.735	0.510
Haiti	2000	1521	0.193	0.933	0.067	0.992	0.992	0.998	0.998	0.998	0.998	0.735	0.606	0.735	0.677	0.735	0.394	0.735	0.677
Honduras	2000	3336	0.750	0.933	0.067	0.981	0.981	0.993	0.993	0.993	0.993	0.735	0.630	0.735	0.630	0.735	0.442	0.735	0.558
Hong Kong	2000	32894	6.098	0.933	0.209	0.933	0.791	0.940	0.940	0.940	0.940	0.927	0.927	0.927	0.927	0.735	0.619	0.735	0.381
Hungary	2000	13129	5.711	0.933	0.082	0.933	0.918	0.943	0.943	0.943	0.943	0.878	0.655	0.878	0.655	0.878	0.477	0.878	0.523
Iceland	2000	33108	10.456	0.933	0.210	0.933	0.790	0.933	0.896	0.933	0.896	0.769	0.769	0.769	0.769	0.735	0.708	0.735	0.292
India	2000	2753	0.927	0.933	0.067	0.984	0.984	0.991	0.991	0.991	0.991	0.885	0.482	0.885	0.680	0.885	0.518	0.885	0.680
Indonesia	2000	5384	1.299	0.933	0.067	0.967	0.967	0.987	0.987	0.987	0.987	0.860	0.565	0.860	0.598	0.860	0.435	0.860	0.598
Iran	2000	9105	5.625	0.933	0.067	0.944	0.944	0.944	0.944	0.944	0.944	0.829	0.635	0.829	0.635	0.829	0.467	0.829	0.533
Iraq	2000	3649	3.052	0.933	0.067	0.978	0.978	0.970	0.970	0.978	0.978	0.735	0.517	0.828	0.828	0.735	0.483	0.828	0.828
Ireland	2000	38807	11.961	0.933	0.247	0.933	0.753	0.933	0.882	0.933	0.882	0.965	0.965	0.965	0.965	0.829	0.573	0.829	0.427
Israel	2000	26059	10.010	0.933	0.165	0.933	0.835	0.933	0.901	0.933	0.901	0.957	0.957	0.957	0.957	0.758	0.758	0.735	0.265
Italy	2000	32717	8.299	0.933	0.208	0.933	0.792	0.933	0.918	0.933	0.918	0.959	0.959	0.959	0.959	0.894	0.894	0.886	0.114
Jamaica	2000	6531	3.885	0.933	0.067	0.960	0.960	0.962	0.962	0.962	0.962	0.893	0.893	0.893	0.893	0.835	0.835	0.735	0.265
Japan	2000	33211	9.915	0.933	0.211	0.933	0.789	0.933	0.902	0.933	0.902	0.967	0.967	0.967	0.967	0.878	0.853	0.878	0.147
Jordan	2000	7622	2.967	0.933	0.067	0.953	0.953	0.971	0.971	0.971	0.971	0.822	0.822	0.822	0.822	0.735	0.555	0.735	0.445
Kazakhstan	2000	9309	9.988	0.933	0.099	0.942	0.942	0.933	0.901	0.942	0.942	0.600	0.400	0.907	0.907	0.815	0.815	0.907	0.907

Kenya	2000	1915	0.325	0.933	0.067	0.990	0.990	0.997	0.997	0.997	0.997	0.764	0.764	0.764	0.764	0.735	0.382	0.735	0.618
Kuwait	2000	35845	26.104	0.933	0.259	0.933	0.772	0.933	0.741	0.933	0.772	0.735	0.407	0.735	0.593	0.735	0.658	0.735	0.658
Kyrgyzstan	2000	3246	0.935	0.933	0.067	0.981	0.981	0.991	0.991	0.991	0.991	0.600	0.400	0.854	0.854	0.968	0.968	0.968	0.968
Laos	2000	2262	0.180	0.933	0.067	0.987	0.987	0.998	0.998	0.998	0.998	0.714	0.286	0.733	0.733	0.939	0.939	0.939	0.939
Latvia	2000	11310	2.970	0.933	0.071	0.933	0.929	0.971	0.971	0.971	0.971	0.600	0.400	0.819	0.819	1.000	1.000	1.000	1.000
Lebanon	2000	7406	4.025	0.933	0.067	0.954	0.954	0.960	0.960	0.960	0.960	0.892	0.892	0.892	0.892	0.735	0.358	0.735	0.642
Lesotho	2000	1967	0.910	0.933	0.067	0.989	0.989	0.991	0.991	0.991	0.991	0.357	0.643	0.875	0.875	0.932	0.932	0.932	0.932
Liberia	2000	972	0.148	0.933	0.067	0.996	0.996	0.999	0.999	0.999	0.999	0.735	0.265	0.860	0.860	0.904	0.904	0.904	0.904
Libya	2000	9771	8.868	0.933	0.088	0.939	0.939	0.933	0.912	0.939	0.939	0.735	0.507	0.735	0.686	0.735	0.493	0.735	0.686
Lithuania	2000	10807	3.392	0.933	0.067	0.933	0.933	0.966	0.966	0.966	0.966	0.600	0.400	0.848	0.848	1.000	1.000	1.000	1.000
Luxembourg	2000	50064	19.972	0.933	0.319	0.933	0.681	0.933	0.802	0.933	0.802	0.820	0.820	0.735	0.265	0.830	0.830	0.830	0.830
Madagascar	2000	1239	0.118	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.735	0.363	0.854	0.854	0.735	0.637	0.854	0.854
Malawi	2000	967	0.078	0.933	0.067	0.996	0.996	0.999	0.999	0.999	0.999	0.736	0.736	0.735	0.265	0.781	0.781	0.781	0.781
Malaysia	2000	13475	5.441	0.933	0.084	0.933	0.916	0.946	0.946	0.946	0.946	0.847	0.630	0.847	0.630	0.847	0.527	0.847	0.473
Mali	2000	1153	0.097	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.695	0.483	0.695	0.612	0.695	0.517	0.695	0.612
Malta	2000	20435	6.467	0.933	0.129	0.933	0.871	0.936	0.936	0.936	0.936	0.811	0.811	0.811	0.811	0.735	0.619	0.735	0.381
Mauritania	2000	1935	0.424	0.933	0.067	0.989	0.989	0.996	0.996	0.996	0.996	0.695	0.414	0.695	0.586	0.772	0.772	0.772	0.772
Mauritius	2000	14272	2.269	0.933	0.090	0.933	0.910	0.978	0.978	0.978	0.978	0.735	0.638	0.735	0.608	0.735	0.638	0.735	0.392
Mexico	2000	12613	4.005	0.933	0.079	0.933	0.921	0.960	0.960	0.960	0.960	0.854	0.737	0.854	0.658	0.854	0.737	0.854	0.342
Moldova	2000	2990	0.850	0.933	0.067	0.983	0.983	0.992	0.992	0.992	0.992	0.600	0.400	0.995	0.995	1.000	1.000	1.000	1.000
Mongolia	2000	2936	3.123	0.933	0.067	0.983	0.983	0.969	0.969	0.983	0.983	0.735	0.265	0.822	0.822	0.813	0.813	0.822	0.822
Montenegro	2000	6046	2.479	0.933	0.067	0.963	0.963	0.975	0.975	0.975	0.975	0.727	0.524	0.750	0.750	0.727	0.476	0.750	0.750
Morocco	2000	4754	1.153	0.933	0.067	0.971	0.971	0.989	0.989	0.989	0.989	0.735	0.613	0.735	0.613	0.735	0.416	0.735	0.584
Mozambique	2000	1196	0.075	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.735	0.265	0.869	0.869	0.974	0.974	0.974	0.974
Myanmar	2000	1843	0.215	0.933	0.067	0.990	0.990	0.998	0.998	0.998	0.998	0.793	0.302	0.793	0.767	0.793	0.698	0.793	0.767
Namibia	2000	5972	0.894	0.933	0.067	0.964	0.964	0.991	0.991	0.991	0.991	0.333	0.667	0.826	0.826	0.827	0.827	0.827	0.827
Nepal	2000	1677	0.127	0.933	0.067	0.991	0.991	0.999	0.999	0.999	0.999	0.735	0.454	0.735	0.546	0.744	0.744	0.744	0.744

Netherlands	2000	37900	10.742	0.933	0.241	0.933	0.759	0.933	0.894	0.933	0.894	0.895	0.793	0.895	0.793	0.895	0.782	0.895	0.218
New Zealand	2000	26823	8.380	0.933	0.170	0.933	0.830	0.933	0.917	0.933	0.917	0.916	0.916	0.916	0.916	0.871	0.714	0.871	0.286
Nicaragua	2000	2859	0.734	0.933	0.067	0.984	0.984	0.993	0.993	0.993	0.993	0.773	0.773	0.773	0.773	0.760	0.240	0.763	0.763
Niger	2000	693	0.061	0.933	0.067	0.997	0.997	0.999	0.999	0.999	0.999	0.700	0.387	1.000	1.000	0.700	0.613	1.000	1.000
Nigeria	2000	2145	0.645	0.933	0.067	0.988	0.988	0.994	0.994	0.994	0.994	0.735	0.622	0.769	0.769	0.735	0.378	0.769	0.769
North Korea	2000	1657	3.017	0.933	0.067	0.991	0.991	0.970	0.970	0.991	0.991	0.832	0.497	0.832	0.624	0.832	0.503	0.832	0.624
North Macedonia	2000	8084	5.895	0.933	0.067	0.950	0.950	0.942	0.942	0.950	0.950	0.775	0.775	0.775	0.775	0.727	0.543	0.727	0.457
Norway	2000	54040	9.373	0.933	0.345	0.933	0.655	0.933	0.907	0.933	0.907	0.968	0.968	0.968	0.968	0.904	0.633	0.904	0.367
Oman	2000	24186	9.496	0.933	0.153	0.933	0.847	0.933	0.906	0.933	0.906	0.667	0.563	0.667	0.563	0.667	0.506	0.667	0.494
Pakistan	2000	3155	0.741	0.933	0.067	0.982	0.982	0.993	0.993	0.993	0.993	0.735	0.608	0.735	0.608	0.735	0.483	0.735	0.517
Palestine	2000	5377	0.515	0.933	0.067	0.967	0.967	0.995	0.995	0.995	0.995	0.650	0.650	0.460	0.643	0.650	0.650	0.540	0.643
Panama	2000	9899	1.890	0.933	0.067	0.938	0.938	0.981	0.981	0.981	0.981	0.743	0.676	0.743	0.676	0.743	0.368	0.743	0.632
Paraguay	2000	4896	0.677	0.933	0.067	0.971	0.971	0.993	0.993	0.993	0.993	0.735	0.542	0.735	0.627	0.735	0.458	0.735	0.627
Peru	2000	6038	1.138	0.933	0.067	0.963	0.963	0.989	0.989	0.989	0.989	0.866	0.577	0.866	0.577	0.866	0.455	0.866	0.545
Philippines	2000	4034	0.928	0.933	0.067	0.976	0.976	0.991	0.991	0.991	0.991	0.838	0.703	0.838	0.703	0.838	0.422	0.838	0.578
Poland	2000	12732	8.240	0.933	0.082	0.933	0.920	0.933	0.918	0.933	0.920	0.917	0.631	0.917	0.631	0.917	0.450	0.917	0.550
Portugal	2000	23372	6.380	0.933	0.148	0.933	0.852	0.937	0.937	0.937	0.937	0.950	0.950	0.950	0.950	0.878	0.857	0.878	0.143
Qatar	2000	45788	57.407	0.933	0.569	0.933	0.708	0.933	0.431	0.933	0.708	0.735	0.564	0.764	0.764	0.735	0.436	0.764	0.764
Romania	2000	7090	4.172	0.933	0.067	0.956	0.956	0.959	0.959	0.959	0.959	0.885	0.458	0.885	0.657	0.885	0.542	0.885	0.657
Russia	2000	10553	10.049	0.933	0.100	0.934	0.934	0.933	0.900	0.934	0.934	0.690	0.310	0.739	0.739	0.725	0.725	0.739	0.739
Rwanda	2000	1024	0.065	0.933	0.067	0.995	0.995	0.999	0.999	0.999	0.999	0.735	0.511	0.741	0.741	0.735	0.489	0.741	0.741
Saint Lucia	2000	7191	2.221	0.933	0.067	0.956	0.956	0.978	0.978	0.978	0.978	0.790	0.790	0.790	0.790	0.735	0.645	0.735	0.355
Sao Tome and Principe	2000	2219	0.335	0.933	0.067	0.988	0.988	0.997	0.997	0.997	0.997	0.731	0.481	0.731	0.595	0.731	0.519	0.731	0.595
Saudi Arabia	2000	23905	14.342	0.933	0.151	0.933	0.849	0.933	0.858	0.933	0.858	0.735	0.672	0.735	0.672	0.735	0.423	0.735	0.577
Senegal	2000	1984	0.398	0.933	0.067	0.989	0.989	0.996	0.996	0.996	0.996	0.700	0.542	0.823	0.823	0.700	0.458	0.823	0.823
Serbia	2000	6060	4.738	0.933	0.067	0.963	0.963	0.953	0.953	0.963	0.963	0.727	0.659	0.727	0.667	0.727	0.341	0.727	0.667

Seychelles	2000	14380	3.890	0.933	0.090	0.933	0.910	0.961	0.961	0.961	0.961	0.673	0.665	0.673	0.665	0.673	0.423	0.673	0.577
Sierra Leone	2000	829	0.072	0.933	0.067	0.997	0.997	0.999	0.999	0.999	0.999	0.735	0.265	0.988	0.988	0.921	0.921	0.988	0.988
Singapore	2000	37773	12.012	0.933	0.240	0.933	0.760	0.933	0.881	0.933	0.881	0.735	0.657	0.735	0.657	0.735	0.536	0.735	0.464
Slovakia	2000	13905	7.622	0.933	0.087	0.933	0.913	0.933	0.925	0.933	0.925	0.455	0.545	0.764	0.764	0.736	0.736	0.764	0.764
Slovenia	2000	21501	7.568	0.933	0.136	0.933	0.864	0.933	0.925	0.933	0.925	0.810	0.810	0.810	0.810	0.727	0.694	0.727	0.306
South Africa	2000	7583	8.412	0.933	0.083	0.953	0.953	0.933	0.917	0.953	0.953	0.866	0.845	0.866	0.845	0.866	0.578	0.866	0.422
South Korea	2000	23108	9.298	0.933	0.146	0.933	0.854	0.933	0.908	0.933	0.908	0.832	0.708	0.832	0.708	0.832	0.600	0.832	0.400
Spain	2000	26995	7.627	0.933	0.171	0.933	0.829	0.933	0.924	0.933	0.924	0.908	0.908	0.908	0.908	0.902	0.812	0.902	0.188
Sri Lanka	2000	5841	0.540	0.933	0.067	0.964	0.964	0.995	0.995	0.995	0.995	0.735	0.407	0.735	0.602	0.735	0.593	0.735	0.602
Sudan	2000	1951	0.185	0.933	0.067	0.989	0.989	0.998	0.998	0.998	0.998	0.735	0.297	0.735	0.703	0.781	0.781	0.781	0.781
Sweden	2000	34203	6.160	0.933	0.217	0.933	0.783	0.939	0.939	0.939	0.939	0.902	0.743	0.902	0.537	0.902	0.743	0.902	0.463
Switzerland	2000	43251	6.106	0.933	0.275	0.933	0.725	0.940	0.940	0.940	0.940	0.888	0.830	0.888	0.830	0.888	0.691	0.888	0.309
Syria	2000	7668	3.076	0.933	0.067	0.953	0.953	0.970	0.970	0.970	0.970	0.920	0.920	0.920	0.920	0.735	0.582	0.735	0.418
Taiwan	2000	26787	10.333	0.933	0.170	0.933	0.830	0.933	0.898	0.933	0.898	0.846	0.846	0.846	0.846	0.846	0.591	0.846	0.409
Tajikistan	2000	1723	0.359	0.933	0.067	0.991	0.991	0.996	0.996	0.996	0.996	0.600	0.400	0.966	0.966	0.976	0.976	0.976	0.976
Tanzania	2000	1149	0.077	0.933	0.067	0.995	0.995	0.999	0.999	0.999	0.999	0.735	0.265	0.785	0.785	0.874	0.874	0.874	0.874
Thailand	2000	9627	2.681	0.933	0.067	0.940	0.940	0.973	0.973	0.973	0.973	0.775	0.635	0.775	0.635	0.775	0.542	0.775	0.458
Togo	2000	1150	0.270	0.933	0.067	0.995	0.995	0.997	0.997	0.997	0.997	0.735	0.500	0.735	0.666	0.735	0.500	0.735	0.666
Trinidad and Tobago	2000	19180	19.091	0.933	0.189	0.933	0.879	0.933	0.811	0.933	0.879	0.735	0.521	0.735	0.514	0.735	0.521	0.735	0.486
Tunisia	2000	7548	2.026	0.933	0.067	0.954	0.954	0.980	0.980	0.980	0.980	0.740	0.740	0.740	0.740	0.735	0.603	0.735	0.397
Turkey	2000	11904	3.634	0.933	0.074	0.933	0.926	0.964	0.964	0.964	0.964	0.878	0.692	0.878	0.692	0.878	0.583	0.878	0.417
Turkmenistan	2000	4173	8.296	0.933	0.082	0.975	0.975	0.933	0.918	0.975	0.975	0.600	0.400	0.944	0.944	0.751	0.751	0.944	0.944
Uganda	2000	1192	0.058	0.933	0.067	0.994	0.994	0.999	0.999	0.999	0.999	0.735	0.281	0.735	0.719	0.735	0.722	0.735	0.722
Ukraine	2000	5166	5.843	0.933	0.067	0.969	0.969	0.942	0.942	0.969	0.969	0.600	0.400	0.911	0.911	0.910	0.910	0.911	0.911
United Arab Emirates	2000	48888	35.668	0.933	0.353	0.933	0.689	0.933	0.647	0.933	0.689	0.695	0.508	0.695	0.492	0.695	0.647	0.695	0.647
United Kingdom	2000	31946	9.633	0.933	0.203	0.933	0.797	0.933	0.905	0.933	0.905	0.933	0.827	0.933	0.796	0.933	0.827	0.933	0.204

United States	2000	45886	21.336	0.933	0.292	0.933	0.708	0.933	0.789	0.933	0.789	0.959	0.959	0.959	0.959	0.917	0.821	0.917	0.179
Uruguay	2000	13050	1.587	0.933	0.082	0.933	0.918	0.984	0.984	0.984	0.984	0.791	0.620	0.791	0.620	0.791	0.556	0.791	0.444
Uzbekistan	2000	4667	4.885	0.933	0.067	0.972	0.972	0.952	0.952	0.972	0.972	0.613	0.613	0.968	0.968	0.600	0.400	0.968	0.968
Venezuela	2000	13993	6.278	0.933	0.088	0.933	0.912	0.938	0.938	0.938	0.938	0.842	0.623	0.842	0.381	0.842	0.623	0.842	0.619
Vietnam	2000	2773	0.658	0.933	0.067	0.984	0.984	0.993	0.993	0.993	0.993	0.829	0.299	0.829	0.701	0.829	0.735	0.829	0.735
World	2000	9915	4.107	0.933	0.067	0.938	0.938	0.959	0.959	0.959	0.959	0.909	0.854	0.909	0.854	0.909	0.625	0.909	0.375
Yemen	2000	4212	0.832	0.933	0.067	0.975	0.975	0.992	0.992	0.992	0.992	0.821	0.821	0.735	0.426	0.821	0.821	0.735	0.574
Zambia	2000	1429	0.171	0.933	0.067	0.993	0.993	0.998	0.998	0.998	0.998	0.735	0.265	0.849	0.849	1.000	1.000	1.000	1.000
Zimbabwe	2000	2211	1.163	0.933	0.067	0.988	0.988	0.988	0.988	0.988	0.988	0.874	0.874	0.735	0.520	0.874	0.874	0.735	0.480
Afghanistan	2018	1935	0.225	1.000	0.011	1.000	0.989	1.000	0.998	1.000	0.998	1.000	0.943	1.000	0.546	1.000	0.943	1.000	0.454
Albania	2018	11104	1.642	1.000	0.069	1.000	0.931	1.000	0.984	1.000	0.984	1.000	1.000	1.000	0.531	1.000	1.000	1.000	0.469
Algeria	2018	14228	3.824	1.000	0.089	1.000	0.911	1.000	0.962	1.000	0.962	1.000	1.000	1.000	1.000	1.000	0.992	1.000	0.008
Angola	2018	7771	0.791	1.000	0.048	1.000	0.952	1.000	0.992	1.000	0.992	1.000	0.879	1.000	0.575	1.000	0.879	1.000	0.425
Argentina	2018	18556	4.082	1.000	0.117	1.000	0.883	1.000	0.960	1.000	0.960	1.000	0.912	1.000	0.862	1.000	0.912	1.000	0.138
Armenia	2018	11454	1.974	1.000	0.072	1.000	0.928	1.000	0.980	1.000	0.980	1.000	1.000	1.000	0.627	1.000	1.000	1.000	0.373
Australia	2018	49831	16.708	1.000	0.318	1.000	0.682	1.000	0.835	1.000	0.835	1.000	1.000	1.000	0.857	1.000	1.000	1.000	0.143
Austria	2018	42988	7.487	1.000	0.274	1.000	0.726	1.000	0.926	1.000	0.926	1.000	1.000	1.000	0.779	1.000	1.000	1.000	0.221
Azerbaijan	2018	16628	3.703	1.000	0.105	1.000	0.895	1.000	0.963	1.000	0.963	1.000	0.942	1.000	0.070	1.000	0.942	1.000	0.930
Bahrain	2018	39499	20.778	1.000	0.251	1.000	0.749	1.000	0.794	1.000	0.794	1.000	0.958	1.000	0.655	1.000	0.958	1.000	0.345
Bangladesh	2018	4099	0.512	1.000	0.024	1.000	0.976	1.000	0.995	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Barbados	2018	11995	4.310	1.000	0.075	1.000	0.925	1.000	0.957	1.000	0.957	1.000	0.851	1.000	0.732	1.000	0.851	1.000	0.268
Belarus	2018	18727	6.449	1.000	0.118	1.000	0.882	1.000	0.936	1.000	0.936	1.000	0.992	1.000	0.139	1.000	0.992	1.000	0.861
Belgium	2018	39756	8.729	1.000	0.253	1.000	0.747	1.000	0.914	1.000	0.914	1.000	1.000	1.000	0.553	1.000	1.000	1.000	0.447
Benin	2018	2220	0.632	1.000	0.012	1.000	0.988	1.000	0.994	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Bolivia	2018	6696	2.101	1.000	0.041	1.000	0.959	1.000	0.979	1.000	0.979	1.000	1.000	1.000	0.998	1.000	1.000	1.000	0.002
Bosnia and Herzegovina	2018	10461	6.641	1.000	0.066	1.000	0.935	1.000	0.934	1.000	0.935	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000

Botswana	2018	15842	3.355	1.000	0.100	1.000	0.900	1.000	0.967	1.000	0.967	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Brazil	2018	14034	2.309	1.000	0.088	1.000	0.912	1.000	0.977	1.000	0.977	1.000	0.880	1.000	0.834	1.000	0.880	1.000	0.166
Bulgaria	2018	18444	6.188	1.000	0.116	1.000	0.884	1.000	0.939	1.000	0.939	1.000	1.000	1.000	0.607	1.000	1.000	1.000	0.393
Burkina Faso	2018	1590	0.218	1.000	0.008	1.000	0.992	1.000	0.998	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Burundi	2018	651	0.061	1.000	0.002	1.000	0.998	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	0.102	1.000	0.898
Cambodia	2018	3629	0.793	1.000	0.021	1.000	0.979	1.000	0.992	1.000	0.992	1.000	1.000	1.000	0.985	1.000	1.000	1.000	0.015
Cameroon	2018	2888	0.315	1.000	0.017	1.000	0.983	1.000	0.997	1.000	0.997	1.000	1.000	1.000	0.427	1.000	1.000	1.000	0.573
Canada	2018	44869	15.630	1.000	0.286	1.000	0.714	1.000	0.845	1.000	0.845	1.000	1.000	1.000	0.844	1.000	1.000	1.000	0.156
Cape Verde	2018	6831	1.098	1.000	0.042	1.000	0.958	1.000	0.989	1.000	0.989	1.000	1.000	1.000	0.884	1.000	1.000	1.000	0.116
Central African Republic	2018	623	0.047	1.000	0.002	1.000	0.998	1.000	1.000	1.000	1.000	1.000	0.233	1.000	0.940	1.000	0.767	1.000	0.940
Chad	2018	2046	0.068	1.000	0.011	1.000	0.989	1.000	0.999	1.000	0.999	1.000	0.819	1.000	0.708	1.000	0.819	1.000	0.292
Chile	2018	22105	4.507	1.000	0.140	1.000	0.860	1.000	0.955	1.000	0.955	1.000	1.000	1.000	0.967	1.000	1.000	1.000	0.033
China	2018	13102	7.208	1.000	0.082	1.000	0.918	1.000	0.929	1.000	0.929	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Colombia	2018	13545	1.709	1.000	0.085	1.000	0.915	1.000	0.983	1.000	0.983	1.000	1.000	1.000	0.883	1.000	1.000	1.000	0.117
Comoros	2018	1724	0.352	1.000	0.009	1.000	0.991	1.000	0.997	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Congo	2018	5715	0.691	1.000	0.035	1.000	0.965	1.000	0.993	1.000	0.993	1.000	0.860	1.000	0.590	1.000	0.860	1.000	0.410
Costa Rica	2018	14686	1.645	1.000	0.092	1.000	0.908	1.000	0.984	1.000	0.984	1.000	1.000	1.000	0.892	1.000	1.000	1.000	0.108
Cote d'Ivoire	2018	3714	0.409	1.000	0.022	1.000	0.978	1.000	0.996	1.000	0.996	1.000	1.000	1.000	0.419	1.000	1.000	1.000	0.581
Croatia	2018	22012	4.258	1.000	0.139	1.000	0.861	1.000	0.958	1.000	0.958	1.000	1.000	1.000	0.713	1.000	1.000	1.000	0.287
Cuba	2018	8326	1.994	1.000	0.051	1.000	0.949	1.000	0.980	1.000	0.980	1.000	1.000	1.000	0.572	1.000	1.000	1.000	0.428
Cyprus	2018	27184	6.172	1.000	0.172	1.000	0.828	1.000	0.939	1.000	0.939	1.000	0.940	1.000	0.749	1.000	0.940	1.000	0.251
Czechia	2018	30749	9.951	1.000	0.195	1.000	0.805	1.000	0.901	1.000	0.901	1.000	1.000	1.000	0.015	1.000	1.000	1.000	0.985
Democratic Republic of Congo	2018	859	0.033	1.000	0.004	1.000	0.996	1.000	1.000	1.000	1.000	1.000	0.502	1.000	0.498	1.000	0.927	1.000	0.927
Denmark	2018	46312	6.028	1.000	0.295	1.000	0.705	1.000	0.940	1.000	0.940	1.000	1.000	1.000	0.419	1.000	1.000	1.000	0.581
Djibouti	2018	3296	0.405	1.000	0.019	1.000	0.981	1.000	0.996	1.000	0.996	1.000	0.482	1.000	0.518	1.000	0.761	1.000	0.761

Dominica	2018	9021	2.251	1.000	0.056	1.000	0.944	1.000	0.978	1.000	0.978	1.000	0.938	1.000	0.866	1.000	0.938	1.000	0.134
Dominican Republic	2018	15912	2.418	1.000	0.100	1.000	0.900	1.000	0.976	1.000	0.976	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Ecuador	2018	10639	2.220	1.000	0.066	1.000	0.934	1.000	0.978	1.000	0.978	1.000	0.958	1.000	0.819	1.000	0.958	1.000	0.181
Egypt	2018	11957	2.314	1.000	0.075	1.000	0.925	1.000	0.977	1.000	0.977	1.000	1.000	1.000	0.890	1.000	1.000	1.000	0.110
El Salvador	2018	8598	0.992	1.000	0.053	1.000	0.947	1.000	0.990	1.000	0.990	1.000	1.000	1.000	0.871	1.000	1.000	1.000	0.129
Equatorial Guinea	2018	28529	8.565	1.000	0.181	1.000	0.819	1.000	0.915	1.000	0.915	1.000	0.615	1.000	0.615	1.000	0.593	1.000	0.407
Estonia	2018	27409	13.564	1.000	0.174	1.000	0.826	1.000	0.866	1.000	0.866	1.000	1.000	1.000	0.533	1.000	1.000	1.000	0.467
Eswatini	2018	8068	0.909	1.000	0.050	1.000	0.950	1.000	0.991	1.000	0.991	1.000	1.000	1.000	0.704	1.000	1.000	1.000	0.296
Ethiopia	2018	1838	0.148	1.000	0.010	1.000	0.990	1.000	0.999	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Finland	2018	38897	8.302	1.000	0.247	1.000	0.753	1.000	0.918	1.000	0.918	1.000	0.968	1.000	0.597	1.000	0.968	1.000	0.403
France	2018	38516	4.960	1.000	0.245	1.000	0.755	1.000	0.951	1.000	0.951	1.000	1.000	1.000	0.475	1.000	1.000	1.000	0.525
Gabon	2018	17614	2.246	1.000	0.111	1.000	0.889	1.000	0.978	1.000	0.978	1.000	0.945	1.000	0.202	1.000	0.945	1.000	0.798
Gambia	2018	1882	0.238	1.000	0.010	1.000	0.990	1.000	0.998	1.000	0.998	1.000	1.000	1.000	0.929	1.000	1.000	1.000	0.071
Georgia	2018	11985	2.524	1.000	0.075	1.000	0.925	1.000	0.975	1.000	0.975	1.000	0.803	1.000	0.803	1.000	0.761	1.000	0.239
Germany	2018	46178	9.072	1.000	0.294	1.000	0.706	1.000	0.910	1.000	0.910	1.000	1.000	1.000	0.635	1.000	1.000	1.000	0.365
Ghana	2018	4267	0.560	1.000	0.025	1.000	0.975	1.000	0.994	1.000	0.994	1.000	1.000	1.000	0.955	1.000	1.000	1.000	0.045
Greece	2018	23451	6.824	1.000	0.148	1.000	0.852	1.000	0.932	1.000	0.932	1.000	0.802	1.000	0.662	1.000	0.802	1.000	0.338
Guatemala	2018	7402	1.081	1.000	0.046	1.000	0.954	1.000	0.989	1.000	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Guinea	2018	1606	0.297	1.000	0.008	1.000	0.992	1.000	0.997	1.000	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Guinea-Bissau	2018	1501	0.166	1.000	0.008	1.000	0.992	1.000	0.998	1.000	0.998	1.000	1.000	1.000	0.678	1.000	1.000	1.000	0.322
Haiti	2018	1729	0.303	1.000	0.009	1.000	0.991	1.000	0.997	1.000	0.997	1.000	1.000	1.000	1.000	1.000	0.583	1.000	0.417
Honduras	2018	5042	1.048	1.000	0.030	1.000	0.970	1.000	0.990	1.000	0.990	1.000	1.000	1.000	0.969	1.000	1.000	1.000	0.031
Hong Kong	2018	50839	5.798	1.000	0.324	1.000	0.676	1.000	0.943	1.000	0.943	1.000	1.000	1.000	0.876	1.000	1.000	1.000	0.124
Hungary	2018	25623	5.090	1.000	0.162	1.000	0.838	1.000	0.950	1.000	0.950	1.000	1.000	1.000	0.579	1.000	1.000	1.000	0.421
Iceland	2018	43439	10.880	1.000	0.277	1.000	0.723	1.000	0.892	1.000	0.892	1.000	1.000	1.000	0.823	1.000	1.000	1.000	0.177
India	2018	6806	1.922	1.000	0.042	1.000	0.958	1.000	0.981	1.000	0.981	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000

Indonesia	2018	11852	2.297	1.000	0.074	1.000	0.926	1.000	0.977	1.000	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Iran	2018	17011	8.645	1.000	0.107	1.000	0.893	1.000	0.914	1.000	0.914	1.000	0.979	1.000	0.979	1.000	0.940	1.000	0.060
Iraq	2018	12836	5.499	1.000	0.080	1.000	0.920	1.000	0.946	1.000	0.946	1.000	0.974	1.000	0.974	1.000	0.914	1.000	0.086
Ireland	2018	64684	8.134	1.000	0.413	1.000	0.587	1.000	0.919	1.000	0.919	1.000	1.000	1.000	0.655	1.000	1.000	1.000	0.345
Israel	2018	32955	7.224	1.000	0.209	1.000	0.791	1.000	0.928	1.000	0.928	1.000	1.000	1.000	0.650	1.000	1.000	1.000	0.350
Italy	2018	34364	5.757	1.000	0.218	1.000	0.782	1.000	0.943	1.000	0.943	1.000	0.942	1.000	0.665	1.000	0.942	1.000	0.335
Jamaica	2018	7273	2.739	1.000	0.045	1.000	0.955	1.000	0.973	1.000	0.973	1.000	0.976	1.000	0.616	1.000	0.976	1.000	0.384
Japan	2018	38674	8.989	1.000	0.246	1.000	0.754	1.000	0.911	1.000	0.911	1.000	1.000	1.000	0.877	1.000	1.000	1.000	0.123
Jordan	2018	11506	2.535	1.000	0.072	1.000	0.928	1.000	0.975	1.000	0.975	1.000	0.984	1.000	0.689	1.000	0.984	1.000	0.311
Kazakhstan	2018	25308	17.319	1.000	0.172	1.000	0.840	1.000	0.828	1.000	0.840	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Kenya	2018	3377	0.351	1.000	0.020	1.000	0.980	1.000	0.997	1.000	0.997	1.000	1.000	1.000	0.875	1.000	1.000	1.000	0.125
Kuwait	2018	65521	23.101	1.000	0.418	1.000	0.582	1.000	0.771	1.000	0.771	1.000	0.817	1.000	0.301	1.000	0.817	1.000	0.699
Kyrgyzstan	2018	5177	1.856	1.000	0.031	1.000	0.969	1.000	0.982	1.000	0.982	1.000	0.747	1.000	0.253	1.000	0.780	1.000	0.780
Laos	2018	6451	2.765	1.000	0.039	1.000	0.961	1.000	0.973	1.000	0.973	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Latvia	2018	24313	4.076	1.000	0.154	1.000	0.846	1.000	0.960	1.000	0.960	1.000	1.000	1.000	0.158	1.000	1.000	1.000	0.842
Lebanon	2018	12559	3.871	1.000	0.079	1.000	0.921	1.000	0.962	1.000	0.962	1.000	0.849	1.000	0.849	1.000	0.729	1.000	0.271
Lesotho	2018	2731	1.225	1.000	0.016	1.000	0.984	1.000	0.988	1.000	0.988	1.000	0.961	1.000	0.538	1.000	0.961	1.000	0.462
Liberia	2018	818	0.225	1.000	0.003	1.000	0.997	1.000	0.998	1.000	0.998	1.000	0.169	1.000	0.896	1.000	0.831	1.000	0.896
Libya	2018	15013	7.990	1.000	0.094	1.000	0.906	1.000	0.921	1.000	0.921	1.000	0.494	1.000	0.506	1.000	0.544	1.000	0.544
Lithuania	2018	27371	4.889	1.000	0.174	1.000	0.826	1.000	0.952	1.000	0.952	1.000	1.000	1.000	0.189	1.000	1.000	1.000	0.811
Luxembourg	2018	57428	15.835	1.000	0.366	1.000	0.634	1.000	0.843	1.000	0.843	1.000	0.980	1.000	0.020	1.000	0.993	1.000	0.993
Madagascar	2018	1428	0.159	1.000	0.007	1.000	0.993	1.000	0.998	1.000	0.998	1.000	0.606	1.000	0.638	1.000	0.394	1.000	0.638
Malawi	2018	1117	0.087	1.000	0.005	1.000	0.995	1.000	0.999	1.000	0.999	1.000	0.980	1.000	0.340	1.000	0.980	1.000	0.660
Malaysia	2018	24842	8.635	1.000	0.157	1.000	0.843	1.000	0.914	1.000	0.914	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Mali	2018	1667	0.192	1.000	0.009	1.000	0.991	1.000	0.998	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Malta	2018	32029	3.502	1.000	0.203	1.000	0.797	1.000	0.965	1.000	0.965	1.000	1.000	1.000	0.392	1.000	1.000	1.000	0.608
Mauritania	2018	3458	0.833	1.000	0.020	1.000	0.980	1.000	0.992	1.000	0.992	1.000	0.999	1.000	0.471	1.000	0.999	1.000	0.529

Mauritius	2018	20139	3.562	1.000	0.127	1.000	0.873	1.000	0.965	1.000	0.965	1.000	1.000	1.000	0.993	1.000	1.000	1.000	0.007
Mexico	2018	16494	3.608	1.000	0.104	1.000	0.896	1.000	0.964	1.000	0.964	1.000	1.000	1.000	0.592	1.000	1.000	1.000	0.408
Moldova	2018	6747	1.341	1.000	0.041	1.000	0.959	1.000	0.987	1.000	0.987	1.000	0.502	1.000	0.498	1.000	0.946	1.000	0.946
Mongolia	2018	13383	14.995	1.000	0.149	1.000	0.916	1.000	0.851	1.000	0.916	1.000	1.000	1.000	0.992	1.000	1.000	1.000	0.008
Montenegro	2018	19504	3.823	1.000	0.123	1.000	0.877	1.000	0.962	1.000	0.962	1.000	1.000	1.000	0.897	1.000	1.000	1.000	0.103
Morocco	2018	8451	1.729	1.000	0.052	1.000	0.948	1.000	0.983	1.000	0.983	1.000	1.000	1.000	0.998	1.000	1.000	1.000	0.002
Mozambique	2018	1133	0.234	1.000	0.005	1.000	0.995	1.000	0.998	1.000	0.998	1.000	0.515	1.000	0.899	1.000	0.485	1.000	0.899
Myanmar	2018	5838	0.609	1.000	0.036	1.000	0.964	1.000	0.994	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Namibia	2018	9043	1.665	1.000	0.056	1.000	0.944	1.000	0.984	1.000	0.984	1.000	0.914	1.000	0.914	1.000	0.901	1.000	0.099
Nepal	2018	2727	0.487	1.000	0.016	1.000	0.984	1.000	0.995	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Netherlands	2018	47474	9.322	1.000	0.302	1.000	0.698	1.000	0.908	1.000	0.908	1.000	1.000	1.000	0.678	1.000	1.000	1.000	0.322
New Zealand	2018	35336	7.546	1.000	0.225	1.000	0.775	1.000	0.925	1.000	0.925	1.000	1.000	1.000	0.815	1.000	1.000	1.000	0.185
Nicaragua	2018	4952	0.817	1.000	0.030	1.000	0.970	1.000	0.992	1.000	0.992	1.000	0.906	1.000	0.860	1.000	0.906	1.000	0.140
Niger	2018	965	0.083	1.000	0.004	1.000	0.996	1.000	0.999	1.000	0.999	1.000	0.542	1.000	0.659	1.000	0.458	1.000	0.659
Nigeria	2018	5238	0.653	1.000	0.032	1.000	0.968	1.000	0.994	1.000	0.994	1.000	0.924	1.000	0.631	1.000	0.924	1.000	0.369
North Korea	2018	1596	0.692	1.000	0.008	1.000	0.992	1.000	0.993	1.000	0.993	1.000	0.337	1.000	0.663	1.000	0.891	1.000	0.891
North Macedonia	2018	13074	3.372	1.000	0.082	1.000	0.918	1.000	0.967	1.000	0.967	1.000	1.000	1.000	0.344	1.000	1.000	1.000	0.656
Norway	2018	84580	8.331	1.000	0.540	1.000	0.460	1.000	0.917	1.000	0.917	1.000	1.000	1.000	0.860	1.000	1.000	1.000	0.140
Oman	2018	36478	12.552	1.000	0.232	1.000	0.768	1.000	0.876	1.000	0.876	1.000	0.782	1.000	0.744	1.000	0.782	1.000	0.256
Pakistan	2018	5510	1.123	1.000	0.033	1.000	0.967	1.000	0.989	1.000	0.989	1.000	1.000	1.000	0.997	1.000	1.000	1.000	0.003
Palestine	2018	5208	0.608	1.000	0.031	1.000	0.969	1.000	0.994	1.000	0.994	1.000	0.660	1.000	0.660	1.000	0.578	1.000	0.422
Panama	2018	22637	2.569	1.000	0.143	1.000	0.857	1.000	0.975	1.000	0.975	1.000	1.000	1.000	0.923	1.000	1.000	1.000	0.077
Paraguay	2018	9339	1.223	1.000	0.058	1.000	0.942	1.000	0.988	1.000	0.988	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Peru	2018	12310	1.708	1.000	0.077	1.000	0.923	1.000	0.983	1.000	0.983	1.000	1.000	1.000	0.867	1.000	1.000	1.000	0.133
Philippines	2018	8139	1.319	1.000	0.050	1.000	0.950	1.000	0.987	1.000	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Poland	2018	27455	8.887	1.000	0.174	1.000	0.826	1.000	0.912	1.000	0.912	1.000	1.000	1.000	0.681	1.000	1.000	1.000	0.319

Portugal	2018	27036	5.021	1.000	0.171	1.000	0.829	1.000	0.950	1.000	0.950	1.000	1.000	1.000	0.747	1.000	1.000	1.000	0.253
Qatar	2018	153764	38.440	1.000	0.984	1.000	0.381	1.000	0.984	1.000	0.619	1.000	0.982	1.000	0.367	1.000	0.982	1.000	0.633
Romania	2018	20126	3.979	1.000	0.127	1.000	0.873	1.000	0.961	1.000	0.961	1.000	1.000	1.000	0.437	1.000	1.000	1.000	0.563
Russia	2018	24669	11.608	1.000	0.156	1.000	0.844	1.000	0.885	1.000	0.885	1.000	1.000	1.000	0.435	1.000	1.000	1.000	0.565
Rwanda	2018	1929	0.093	1.000	0.010	1.000	0.990	1.000	0.999	1.000	0.999	1.000	1.000	1.000	0.749	1.000	1.000	1.000	0.251
Saint Lucia	2018	10475	2.800	1.000	0.065	1.000	0.935	1.000	0.972	1.000	0.972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Sao Tome and Principe	2018	3730	0.625	1.000	0.022	1.000	0.978	1.000	0.994	1.000	0.994	1.000	1.000	1.000	0.992	1.000	1.000	1.000	0.008
Saudi Arabia	2018	50305	18.454	1.000	0.321	1.000	0.679	1.000	0.817	1.000	0.817	1.000	0.971	1.000	0.866	1.000	0.971	1.000	0.134
Senegal	2018	2617	0.715	1.000	0.015	1.000	0.985	1.000	0.993	1.000	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Serbia	2018	14124	5.028	1.000	0.089	1.000	0.911	1.000	0.950	1.000	0.950	1.000	1.000	1.000	0.711	1.000	1.000	1.000	0.289
Seychelles	2018	29531	5.736	1.000	0.187	1.000	0.813	1.000	0.943	1.000	0.943	1.000	1.000	1.000	0.993	1.000	1.000	1.000	0.007
Sierra Leone	2018	1684	0.125	1.000	0.009	1.000	0.991	1.000	0.999	1.000	0.999	1.000	0.729	1.000	0.271	1.000	0.774	1.000	0.774
Singapore	2018	68402	7.990	1.000	0.437	1.000	0.563	1.000	0.921	1.000	0.921	1.000	1.000	1.000	0.433	1.000	1.000	1.000	0.567
Slovakia	2018	27076	6.607	1.000	0.172	1.000	0.828	1.000	0.935	1.000	0.935	1.000	1.000	1.000	0.077	1.000	1.000	1.000	0.923
Slovenia	2018	29245	6.975	1.000	0.186	1.000	0.814	1.000	0.931	1.000	0.931	1.000	1.000	1.000	0.732	1.000	1.000	1.000	0.268
South Africa	2018	12166	8.032	1.000	0.080	1.000	0.924	1.000	0.920	1.000	0.924	1.000	0.993	1.000	0.807	1.000	0.993	1.000	0.193
South Korea	2018	37928	13.125	1.000	0.241	1.000	0.759	1.000	0.870	1.000	0.870	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Spain	2018	31497	5.776	1.000	0.200	1.000	0.800	1.000	0.943	1.000	0.943	1.000	0.957	1.000	0.688	1.000	0.957	1.000	0.312
Sri Lanka	2018	11663	0.989	1.000	0.073	1.000	0.927	1.000	0.990	1.000	0.990	1.000	1.000	1.000	0.887	1.000	1.000	1.000	0.113
Sudan	2018	3380	0.507	1.000	0.020	1.000	0.980	1.000	0.995	1.000	0.995	1.000	0.943	1.000	0.943	1.000	0.869	1.000	0.131
Sweden	2018	45542	4.222	1.000	0.290	1.000	0.710	1.000	0.958	1.000	0.958	1.000	1.000	1.000	0.368	1.000	1.000	1.000	0.632
Switzerland	2018	61373	4.324	1.000	0.392	1.000	0.608	1.000	0.957	1.000	0.957	1.000	1.000	1.000	0.586	1.000	1.000	1.000	0.414
Syria	2018	3349	1.792	1.000	0.020	1.000	0.980	1.000	0.982	1.000	0.982	1.000	0.522	1.000	0.962	1.000	0.478	1.000	0.962
Taiwan	2018	44664	11.921	1.000	0.284	1.000	0.716	1.000	0.882	1.000	0.882	1.000	1.000	1.000	0.977	1.000	1.000	1.000	0.023
Tajikistan	2018	4440	1.001	1.000	0.027	1.000	0.973	1.000	0.990	1.000	0.990	1.000	0.581	1.000	0.419	1.000	0.742	1.000	0.742
Tanzania	2018	2875	0.209	1.000	0.017	1.000	0.983	1.000	0.998	1.000	0.998	1.000	1.000	1.000	0.973	1.000	1.000	1.000	0.027

Thailand	2018	16649	3.978	1.000	0.105	1.000	0.895	1.000	0.961	1.000	0.961	1.000	1.000	1.000	0.943	1.000	1.000	1.000	0.057
Togo	2018	1451	0.290	1.000	0.007	1.000	0.993	1.000	0.997	1.000	0.997	1.000	0.693	1.000	0.540	1.000	0.693	1.000	0.460
Trinidad and Tobago	2018	28549	29.122	1.000	0.288	1.000	0.819	1.000	0.712	1.000	0.819	1.000	0.887	1.000	0.814	1.000	0.887	1.000	0.186
Tunisia	2018	11354	2.539	1.000	0.071	1.000	0.929	1.000	0.975	1.000	0.975	1.000	1.000	1.000	0.965	1.000	1.000	1.000	0.035
Turkey	2018	19270	5.094	1.000	0.122	1.000	0.878	1.000	0.950	1.000	0.950	1.000	0.971	1.000	0.971	1.000	0.970	1.000	0.030
Turkmenista n	2018	26318	12.040	1.000	0.167	1.000	0.833	1.000	0.881	1.000	0.881	1.000	1.000	1.000	0.899	1.000	1.000	1.000	0.101
Uganda	2018	2045	0.129	1.000	0.011	1.000	0.989	1.000	0.999	1.000	0.999	1.000	1.000	1.000	0.814	1.000	1.000	1.000	0.186
Ukraine	2018	9813	5.244	1.000	0.061	1.000	0.939	1.000	0.948	1.000	0.948	1.000	0.837	1.000	0.163	1.000	0.973	1.000	0.973
United Arab Emirates	2018	76398	16.011	1.000	0.488	1.000	0.512	1.000	0.841	1.000	0.841	1.000	0.996	1.000	0.158	1.000	0.996	1.000	0.842
United Kingdom	2018	38058	5.688	1.000	0.242	1.000	0.758	1.000	0.944	1.000	0.944	1.000	1.000	1.000	0.432	1.000	1.000	1.000	0.568
United States	2018	55335	16.434	1.000	0.353	1.000	0.647	1.000	0.837	1.000	0.837	1.000	1.000	1.000	0.739	1.000	1.000	1.000	0.261
Uruguay	2018	20186	1.905	1.000	0.128	1.000	0.872	1.000	0.981	1.000	0.981	1.000	1.000	1.000	0.746	1.000	1.000	1.000	0.254
Uzbekistan	2018	11220	3.533	1.000	0.070	1.000	0.930	1.000	0.965	1.000	0.965	1.000	1.000	1.000	0.097	1.000	1.000	1.000	0.903
Venezuela	2018	10710	4.160	1.000	0.067	1.000	0.933	1.000	0.959	1.000	0.959	1.000	0.457	1.000	0.543	1.000	0.747	1.000	0.747
Vietnam	2018	6814	2.342	1.000	0.042	1.000	0.958	1.000	0.977	1.000	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
World	2018	15212	4.802	1.000	0.096	1.000	0.904	1.000	0.952	1.000	0.952	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Yemen	2018	2285	0.350	1.000	0.013	1.000	0.987	1.000	0.997	1.000	0.997	1.000	0.248	1.000	0.752	1.000	0.823	1.000	0.823
Zambia	2018	3534	0.422	1.000	0.021	1.000	0.979	1.000	0.996	1.000	0.996	1.000	1.000	1.000	0.171	1.000	1.000	1.000	0.829
Zimbabwe	2018	1611	0.821	1.000	0.008	1.000	0.992	1.000	0.992	1.000	0.992	1.000	0.395	1.000	0.605	1.000	0.725	1.000	0.725

Supplementary Table. Chebyshev distance calculations for all countries in absolute and relative environments.
The table lists the Chebyshev distance between six vertices of unit cube and country data points in years 1750, 1800, 1850, 1900, 1950, 2000, 2018, both in relative and absolute environments. For illustration purposes, only three decimal places could be designated in the table; for complete calculations for all years, please see the output file from the available code. The vertex numbers are decimal conversions of the binary nomenclature discussed in Methods section, i.e., the vertex (1, 0, 0) having the order of (x, y, z) holds the binary code of 001 and the decimal conversion is 1, i.e. 'Vrtx 1'.

5.2 *Data and Code Availability*

The results can be reproduced based on the public data available from the following GitHub link by *Our World in Data*[60][61] (https://github.com/owid/co2-data) and the Python code below. IPython and Plotly are used for visualization purposes.

```
import plotly.offline as pyo
import plotly.express as px
import plotly.graph_objects as go
pyo.init_notebook_mode()
import pandas as pd

## reading the dataframe
df = pd.read_csv(r"co2-emissions-vs-gdp.csv")

## renaming the column name of "Entity" to "Country"
df = df.rename(columns={"Entity": "Country"})

## countries to be dropped (in case needed)
#outlier_countries = []

## removing the outlier countries
#df = df[~df["Country"].isin(outlier_countries)]

## countries to keep (in case only certain countries are desired)
#only_countries = ["World"]
# keeping only the only_countries
#df = df[df["Country"].isin(only_countries)]

## keeping ceratin years: here those are years between 1750 and 2020
df = df.loc[(df['Year'] >= 1750) & (df['Year'] <= 2020)]

## in case needed, filtering data based on more features
#df = df.loc[(df['GDP per capita'] >= 9000) & (df['GDP per capita'] <= 10000) | (df['Year'] <
= 1903) | (df['Year'] >= 2017)]

## keeping only rows with available data for CO2 emissions AND per capita of GDP AND Year
df = df.dropna(subset=["Annual CO2 emissions (per capita)", "GDP per capita", "Year"], how='
any')

## removing the column with the name "145446-annotations"! This line is redundant, see below
.

df = df.drop("145446-annotations", axis = 1)
```

```
## drop other columns that are currently extra. Please hash (#) each of them, when necessary
## the below lines are redundant (for use when necessary). See the reordering datafarme below.
df = df.drop("Population (historical estimates)", axis = 1)
df = df.drop("Code", axis = 1)
df = df.drop("Continent", axis = 1)

## changing the column orders to be in the order of x, y, z. That is: Year, GDP, CO2
## revise this order when necessary. coordinate system is z-up
df = df[["Country", "Year", "GDP per capita", "Annual CO2 emissions (per capita)"]]

#################################################################
## Calculations for the relative space
################################################
## defining the numerical columns that need to be normalized in RELATIVE environment
norm_cols = ["Year", "GDP per capita", "Annual CO2 emissions (per capita)"]
df[["Year (rel)", "GDP (rel)", "CO2 (rel)"]] = df[norm_cols].apply(lambda x: (x - x.min()) / (x.
max() - x.min()))

## renaming the columns for an easier usage in the code
#df = df.rename(columns = {"Annual CO2 emissions (per capita)":"CO2", "GDP per capita":"
GDP"})

## changing the column orders to be in the order of x, y, z. That is: Year, GDP, CO2
# revise this order when necessary. coordinate system is z-up. This line is redundant.
df = df[["Country", "Year", "GDP per capita", "Annual CO2 emissions (per capita)", "Year (rel)
", "GDP (rel)", "CO2 (rel)"]]

## calculating the reverse of each column
df["1 - Year (rel)"] = 1 - df["Year (rel)"]
df["1 - GDP (rel)"] = 1 - df["GDP (rel)"]
df["1 - CO2 (rel)"] = 1 - df["CO2 (rel)"]

## defining the new columns of results (for each of the vertexes): Chebyshev distance between v
ertices and data points in relative environment
df = df.assign(dist_from_vrtx0_rel = df[["Year (rel)", "GDP (rel)", "CO2 (rel)"]].max(axis=1),
               dist_from_vrtx1_rel = df[["1 - Year (rel)", "GDP (rel)", "CO2 (rel)"]].max(axis=1),
              dist_from_vrtx2_rel = df[["Year (rel)", "1 - GDP (rel)", "CO2 (rel)"]].max(axis=1),
              dist_from_vrtx3_rel = df[["1 - Year (rel)", "1 - GDP (rel)", "CO2 (rel)"]].max(axis=1),
              dist_from_vrtx4_rel = df[["Year (rel)", "GDP (rel)", "1 - CO2 (rel)"]].max(axis=1),
              dist_from_vrtx5_rel = df[["1 - Year (rel)", "GDP (rel)", "1 - CO2 (rel)"]].max(axis=1),
              dist_from_vrtx6_rel = df[["Year (rel)", "1 - GDP (rel)", "1 - CO2 (rel)"]].max(axis=1),
              dist_from_vrtx7_rel = df[["1 - Year (rel)", "1 - GDP (rel)", "1 - CO2 (rel)"]].max(axis=
1))
```

```
##############################################################
## Calculations for the absolute space
##############################################
## defining the numerical columns that need to be normalized in ABSOLUTE environment
norm_cols = ["Year", "GDP per capita", "Annual CO2 emissions (per capita)"]
df[["Year (abs)", "GDP (abs)", "CO2 (abs)"]] = df.groupby("Country")[norm_cols].transform(la
mbda x: (x - x.min()) / (x.max() - x.min()))

## calculating the reverse of each column
df["1 - Year (abs)"] = 1 - df["Year (abs)"]
df["1 - GDP (abs)"] = 1 - df["GDP (abs)"]
df["1 - CO2 (abs)"] = 1 - df["CO2 (abs)"]

## defining the new columns of results (for each of the vertexes): Chebyshev distance between v
ertices and data points in absolute environment
df = df.assign(dist_from_vrtx0_abs = df[["Year (abs)", "GDP (abs)", "CO2 (abs)"]].max(axis=1
),
         dist_from_vrtx1_abs = df[["1 - Year (abs)", "GDP (abs)", "CO2 (abs)"]].max(axis=1),
        dist_from_vrtx2_abs = df[["Year (abs)", "1 - GDP (abs)", "CO2 (abs)"]].max(axis=1),
        dist_from_vrtx3_abs = df[["1 - Year (abs)", "1 - GDP (abs)", "CO2 (abs)"]].max(axis=
1),
        dist_from_vrtx4_abs = df[["Year (abs)", "GDP (abs)", "1 - CO2 (abs)"]].max(axis=1),
        dist_from_vrtx5_abs = df[["1 - Year (abs)", "GDP (abs)", "1 - CO2 (abs)"]].max(axis=
1),
        dist_from_vrtx6_abs = df[["Year (abs)", "1 - GDP (abs)", "1 - CO2 (abs)"]].max(axis=
1),
        dist_from_vrtx7_abs = df[["1 - Year (abs)", "1 - GDP (abs)", "1 - CO2 (abs)"]].max(axi
s=1))

## showing results, where necessary
#df.head(50)

## saving results
df.to_csv("results.csv", index=False)

## plotting a 3D line plot, where necessary
#fig = px.line_3d(df, x="Year", y="GDP per capita", z="Annual CO2 emissions (per capita)",
color='Country')
#fig.update_layout(width=800, height=800, autosize=False, scene=dict(camera=dict(up=dict(
x=0,y=0,z=1),
#        eye=dict(x=0,y=1.0707,z=1,)), aspectratio = dict( x=1, y=1, z=1 ), aspectmode = 'ma
nual'))
#fig.show()
```

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