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The Demotechnic Index of Nations, 1980-2018

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by

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ABSTRACT

The Demotechnic Index (DI) is a non-dimensional metric that is the scalar multiple of energy consumption over and above that required for mere subsistence of a national population. Thus, the DI is a measure of energy efficiency that scales a country's industrial energy consumption (called the total technological energy) and the energy required to meet the metabolic demand of the population (called the total metabolic energy). The DI was created by scientist John Vallentyne in 1982, refined in 1994, but never gained popularity or wide use as a sustainability metric. The objective of this thesis was to re-evaluate the DI as a metric of national energy use and determine the trajectory of the DI for United Nations-member states over the last four decades (1980-2018). Tracking the DI of nations over time shows that the DI is sensitive to economic, social, and political events and has utility in telling stories about the past, and how world and regional events shaped the world we live in today. The multidecadal record of national DIs is a complex record documenting the evolution of total energy consumption, the interplay of different energy sources over time, interactions between humans and the environment, the impacts of economics, conflict, and social upheaval, and our energy choices on the well-being of nations and their people. The Demotechnic Index illustrates this all and thus, seems worthy of greater investigation that may yield insights to be intelligently considered and used to strategize future human progress.

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INTRODUCTION

The primary goal of this thesis was to reintroduce the Demotechnic Index (DI; Vallentyne, 1982; Mata et al., 2012) as a measure of national energy consumption and track the progress of the DI of United Nations-member states over 40-years (1980 – 2018) to determine their energy trajectories.

In 1982, Vallentyne introduced the DI, that focused on energy consumption by a national population. The DI recognized that not all human populations utilized energy uniformly. Some populations used greater quantities of energy than others. The DI relates a country's energy consumption to its population.

In a white-paper originally presented at the United Nations summit on Population and Development in Cairo, Egypt in 1994, and later published in 2012, scientists Francisco J. Mata, Lawrence J. Onisto, and John Vallentyne defined the DI as “the ratio of technological energy consumption to physiological energy consumption with both expressed in common units,” which “provides a measure of the technological metabolism associated with an average person in a specific national or regional setting” (Mata et al. 2012). This paper also provided a snapshot of nation-level DIs for a single year (1990) for UN-member states.

In the decades since introduction of the DI, the effects of human population growth on our planet became increasingly evident. Scientists are now more aware than ever of the strain that burgeoning population places on the consumption of natural resources and on our planetary ecosystem. Furthermore, exponentially increasing global population increases energy consumption exponentially, exacerbating the climate crisis.

For years, scientists focused attention almost exclusively on effects of population growth on resource consumption because exponential population growth was considered the primary driver of resource consumption (Hardin, 1968; Erlich, 1968). In his essay, “The Tragedy of the Commons”, ecologist Garrett Hardin (1968) provided insight into the human dynamics of resource consumption. In addition, Hardin (1968) expounded on energy consumption by humans. He categorized two energy classes: metabolic and technological energy.

Hardin (1968) explained metabolic energy. “To live, any organism must have a source of energy (for example, food). This energy is utilized for two purposes: mere [physiological] maintenance and [physiological] work. For man, maintenance of life requires about 1,600 kilocalories [6,694 kJ] per day” ("maintenance calories"; Hardin 1968). These “maintenance calories” are the minimum energy intake our bodies require to survive. More recent, detailed investigations of human metabolic needs indicate that approximately 9,626 kJ/d is the optimum energy intake for an average adult to function and thrive (Boss et al. 2018; DHHS-USDA, 2015; NHMRC, 2015; Australian Health Survey, 2013; Mata et al. 2012; FAO Statistics Division, 2008; Cavill et al., 2006; Scientific Committee for Food, 1992; Périssé, J. 1981). The energy ingested by humans for physiological function is termed metabolic energy by Hardin (1968). Metabolic energy is represented by the variable, E_M, in the calculation of the DI.

Hardin (1968) identifies another form of energy exploited by humanity. It is the energy humanity utilizes to do “work” in the environment. Work energy, as he calls it, is “Anything that (man) does over and above merely staying alive,” and includes not only “what we call work in common speech; [energy is] also required for all forms of enjoyment, from swimming and automobile racing to playing music and writing poetry" (Hardin, 1968). Of course, this work energy also includes all the industrial components that make these activities possible, such as electricity, transportation, and systems of mass production for food, products, etc. Thus, Hardin's work energy (1968) is technological energy as described by Valentine (1982) and Mata et al. (2012) in their formulation of the DI. Technological energy is designated by the variable, E_T, in the formula for the DI.

With these definitions in mind, the DI described by Mata et al. (2012) cleverly utilizes metabolic energy and technological energy to objectively and meaningfully compare energy consumption of nations. For this thesis, the DI was calculated for all UN-member states for years 1980-2018 to determine trajectories of energy use by national populations. Of interest in the exercise was to determine increasing, decreasing, or varying trajectories through time and to assess influences on national trajectories and the implications of those influences on energy consumption of national populations worldwide during the modern era.

In addition, tracking the multi-decadal timeline of the DI permitted examination of the impacts of global, regional, or state-level events (e.g. economic recessions, armed conflict, natural disasters, or national sovereignty) on national energy consumption. To illustrate this aspect, there are several noteworthy historical events since 1980 that played a large role in shaping the world as we know it today. For example, the collapse of the Soviet Union (1989-1991), the 9/11 terrorist attacks and Global War on Terror (GWOT) that followed, the Arab Spring revolutions from 2011-2013, and the global financial crisis of 2008. These events had global socio-economic impacts and it is hypothesized that they could alter the DI of many nations.

Aside from examining the DI in historical context, geography may have physical and social influences on national energy consumption and these influences may also impact the DI. Logically, a country with a larger population would be expected to exhibit high energy consumption simply because more people utilize more energy. However, this is not always the case. The DI exposes how the lifestyle of a country's citizens is an important aspect in determining that country's energy utilization. Regardless of population size, those who live in excess will place higher on the DI, and those with fewer resources and infrastructure at their disposal will place lower. Thus, the DI may also serve as a proxy for human well-being reflecting real life behaviors and actions in countries with drastically different population sizes.

By studying the DI, we anticipate that much can be learned about the dynamics of energy consumption, national characteristics, and recent world history. The implications of conflict, resource scarcity, and sustainable development may find expression in the DI. As we currently face a climate crisis, global pandemic, and military conflicts around the globe, it is imperative now more than ever that we understand how our actions as consumers and global citizens shape the future. The DI is just one of the many tools that can aid in this understanding.

METHODS

The DI is a metric calculated using a simple formula that is, "a ratio of technological energy consumption to physiological energy consumption with both expressed in common units" (Mata et al. 2012). To begin, the total annual metabolic energy intake of a person from food is estimated using a consensus value for the daily energy requirement of an adult (ca. 9,626 kJ/day; Boss et al. 2018; DHHS-USDA, 2015; NHMRC, 2015; Australian Health Survey, 2013; Mata et al. 2012; FAO Statistics Division, 2008; Cavill et al., 2006; Scientific Committee for Food, 1992; Périssé, J. 1981) and multiplied by 365.25 days in 1-year: 1 person x 9,626 kJ/d x 365.25 d = D-Unit.

$$\mathbf{1\ person \times 9,626\frac{kJ}{d} \times 365.25\ d = D - unit}$$ (1) (Mata et al. 2012)

This estimate is called the D-unit, and has a value of 3.52×10^6 kJ. The D-Unit is multiplied by a national population to derive the total metabolic energy (E_M) required each year by a nation:

$$\mathbf{D - unit \times Population = E_M}$$ (2) (Mata et al. 2012)

Total technological energy is the energy that a country consumes for all functions over a above the optimum for survival, such as for transportation, production of electricity, and industrial means, etc. and is measured in kilojoules (kJ). Total technological energy is designated by the variable, E_T, in the DI formula. The full formula for the DI was presented in Mata et al (2012):

$$\mathbf{DI = \frac{(E_T + E_M) - E_M}{E_M}}$$ (3) (Mata et al. 2012)

where, E_T is total technological energy (kJ) and E_M is the total metabolic energy (kJ) of a population. Thus, the DI is a dimensionless value representing the scalar multiple of energy use over and above that required for mere subsistence of a population.

To calculate E_T, data were acquired from the U.S. Energy Information Administration (EIA, https://www.eia.gov). This website contains data regarding energy consumption and production from every UN-member state since 1980. After downloading the relevant data tables, they were sorted by energy type using spreadsheet software. These energy types included various non-renewable and renewable energy resources. The raw energy data were provided in quadrillion British Thermal Units (10^{15} BTU) and converted to kilojoules (kJ) using the conversion factor 1 quadrillion BTU = $1055.6*10^{12}$ kJ.

To calculate E_M, population data for each UN-member state were obtained from the United Nations website (United Nations, https://population.un.org/wpp/) which provided the population (in thousands) of every UN country from 1950 - 2020. The total human metabolic energy demand was calculated by multiplying the UN population data by 1000 to get the exact population number. The total population was then multiplied by the D-Unit to obtain the total metabolic energy of a country's population for one year in kJ.

Once E_T and E_M were calculated, the DI was calculated for each country annually from 1980-2018 using equation (3) above. DI data were sorted from highest to lowest value to create DI rankings by country by year, and I began to analyze patterns in the data, some of which will be highlighted in the next section of this thesis.

RESULTS

Appendix 1 presents the total technologic energy consumed by countries from 1980-2018. These data were obtained from the Energy Information Administration (EIA; https://www.eia.gov). The table shows the total technological energy consumed (in quad

BTU), as well as consumption of coal, natural gas, petroleum, nuclear, and renewable energy sources by every UN-member state.

Appendix 2 presents the total metabolic energy (kJ/year) consumed by countries' populations from 1980-2018. Population data were obtained from the United Nations website (https://population.un.org/wpp/).

Appendix 3 presents the calculated DI for countries from 1980-2018. These data were calculated using the total technological energy and the total metabolic energy of nations in equation (3).

Appendix 4 shows the 2018 DIs of countries ranked from greatest to least. There were 216 countries present in the DI dataset for this year.

Appendix 5 is a global map of the 2018 DI. Countries are colored according to where their DI falls along the gradient scale in the legend, which follows the distribution of DI scores. This same map is also shown in Figure (2), but the original, full resolution image is included here where it can be viewed and analyzed more closely using imaging software.

In 2018, the most recent year of data availability, there were 216 U.N. member states. The observed range of DI in 2018 spans 5 orders of magnitude. In 2018, Gibraltar had the highest DI (1,654.32) whereas the central African nation of Burundi had the lowest DI (0.22). This large disparity in DI scores reflects the very high energy utilization associated with intensive military and tourism activity by a small population (Gibraltar, population ca. 34k) versus subsistence-level energy utilization by a large population (Burundi, population >11.175M).

The trajectory of the globally averaged DI was increasing for the 1980-2018 interval. Figure 1 tracks the mean and median DI of nations over these 40-years.

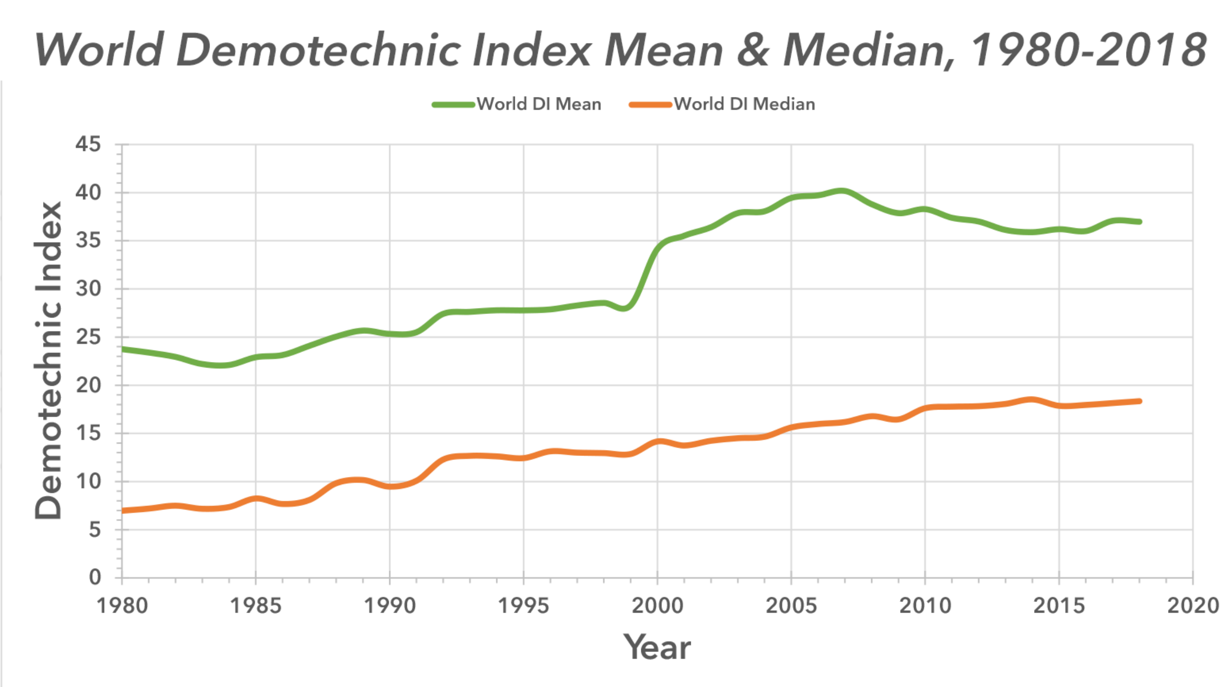

Fig. 1. *Trajectory of the mean (green), and median (orange) DI of the world from 1980-2018.*

In Figure 1, the mean DI of nations (green line) was derived from the calculated DI of nations for each year from 1980-2018. The median DI (orange line) represents the median (i.e., 50% of national D-Indices are greater and 50% of national D-Indices are lower than the median) determined from the DI of nations for each year from 1980-2018.

The mean DI (Fig. 1, green line) increased slowly but steadily from 1980 to 1999. From 1999 to 2000, there was a dramatic mean-shift from DI of ca. 29 to ca. 35. This shift resulted primarily from a large increase in the DI of Gibraltar, from 422 in 1999 to 1,160 in 2000. The 2.8-fold increase in DI was driven by a 2.8-fold increase in total energy consumption. Until 2019, 100% of Gibraltar's electric power was generated from 40 diesel-fueled generators (Gibraltar 2014), but the cause of increased consumption from 1999-2000 was not determined. Gibraltar has a very small permanent population (ca. 34k) but is visited by ca. 10M tourists annually. Thus, it has an over-sized energy footprint and correspondingly extreme DI with an out-sized influence on the calculation of the global mean DI.

The trajectory of the median global DI (Fig. 1; orange line) also increases steadily from 1980 to 1991. From 1991 to 1992, the median DI shifts approximately 45% (from 8.8 to 12.1), then continues its upward trajectory to 2018 at a rate similar to the pre-1992 rate. The prominent shift in the global median DI from 1991 to 1992 resulted from two sources. The collapse of the USSR and soviet bloc states in 1989-1991 introduced 18 newly-independent nations to the list of nations for this study (Table 1). All initial DIs of these nations exceeded the median 1991 DI by a significant margin (range from 10.58 – 81.85; Table 1). In addition, Kuwait emerged from its occupation by Iraq and subsequent liberation during the Desert Storm conflict, increasing its DI from 31.9 to 55.1. Both of these events shifted the median global DI during 1991 – 1992.

Country	*D-Index*	*Country*	*D-Index*
Armenia	**17.18**	**Latvia**	**25.00**
Azerbaijan	**39.94**	**Lithuania**	**39.07**
Belarus	**44.53**	**Moldova**	**14.61**
Bosnia and Herzegovina	**10.58**	**Republic of North Macedonia**	**15.75**
Croatia	**19.81**	**Slovenia**	**33.94**
Estonia	**22.91**	**Tajikistan**	**15.46**
Georgia	**18.24**	**Turkmenistan**	**23.08**
Kazakhstan	**81.85**	**Ukraine**	**53.72**
Kyrgyzstan	**19.08**	**Uzbekistan**	**23.6**

Table 1. *Independent nations (with DI) introduced to the list of nations for this study following the collapse of the USSR from 1989-1992.*

Figure 2 is a map showing the 2018 DI of nations. Colors correspond to the DI scores, with blue = high DI and red = low DI (see gradient scale in the legend; Fig. 2). Although many small countries and islands are not visible in Fig. 2, the map includes all 216 countries included in the 2018 DI, and the original high-resolution image is available in native digital format as Appendix 5 so it can be viewed in full detail.

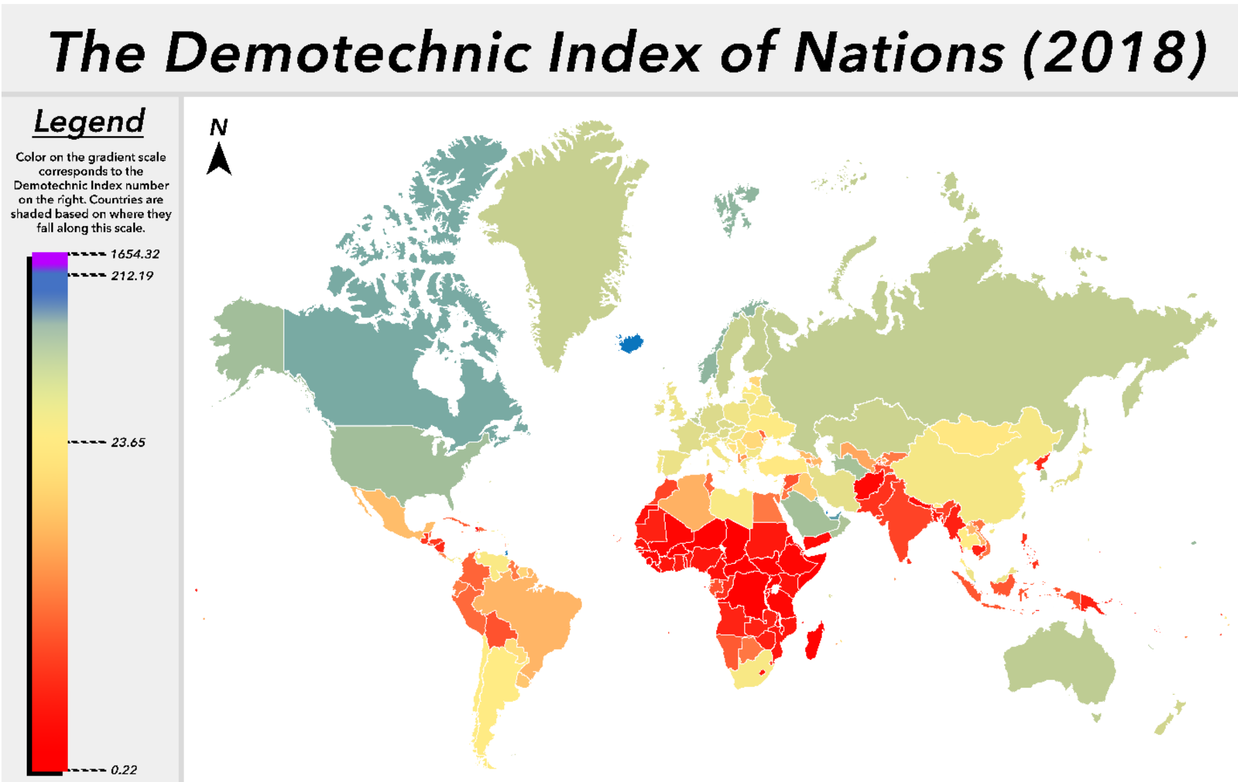

Fig. 2. A global map of the Demotechnic Index for all nations in 2018. Countries are colored according to where their DI falls along the gradient scale on the left, which follows the distribution of DI scores.

On the scale, purple marks the highest DI score, which is Gibraltar (1,654.32). Because there is a large difference between the 1st and 2nd place countries, purple quickly fades to blue as one moves down the scale. Blue marks the 2nd place DI score, which is Qatar (212.19). There is a medium sized gap as blue fades to yellow, which marks the mean DI at 23.65. There is a large gap as yellow fades to red, which sits at the bottom of the scale and marks the lowest DI score, which is Burundi (0.22). The size of the gaps between colors on the scale mimics the distribution of the DI, and it is clear to see that nearly 2/3 of countries in the world sit below the mean DI. In other words, there are many more “have-nots” than “haves” in the world.

Indeed, a pattern that emerges immediately is the disparity in DI between countries in the northern hemisphere and those in the southern hemisphere. Most countries in the northern hemisphere are colored some shade of blue, green, or yellow, putting them above or around the mean DI. This is true for regions such as the U.S. & Canada, Western Europe, the Nordic states (the developed “Global North”), oil rich nations in the Middle East, and northern Asia. In contrast, most countries in the southern hemisphere are colored some shade of yellow, orange, or red, putting them at or below the mean DI. This is true for regions such as Central and South America, Africa, Eastern Europe, war-torn countries in the Middle East, and Southern Asia. Australia and New Zealand are exceptions to this pattern, as they are the only countries below the equator that are colored green.

Because the DI is a measure of energy consumption, a country’s development status can be inferred by looking at its color on the map. Countries in blue or green are more developed, countries in green-yellow, yellow, or yellow-orange are emerging nations, and countries in orange or red are developing and underdeveloped nations.

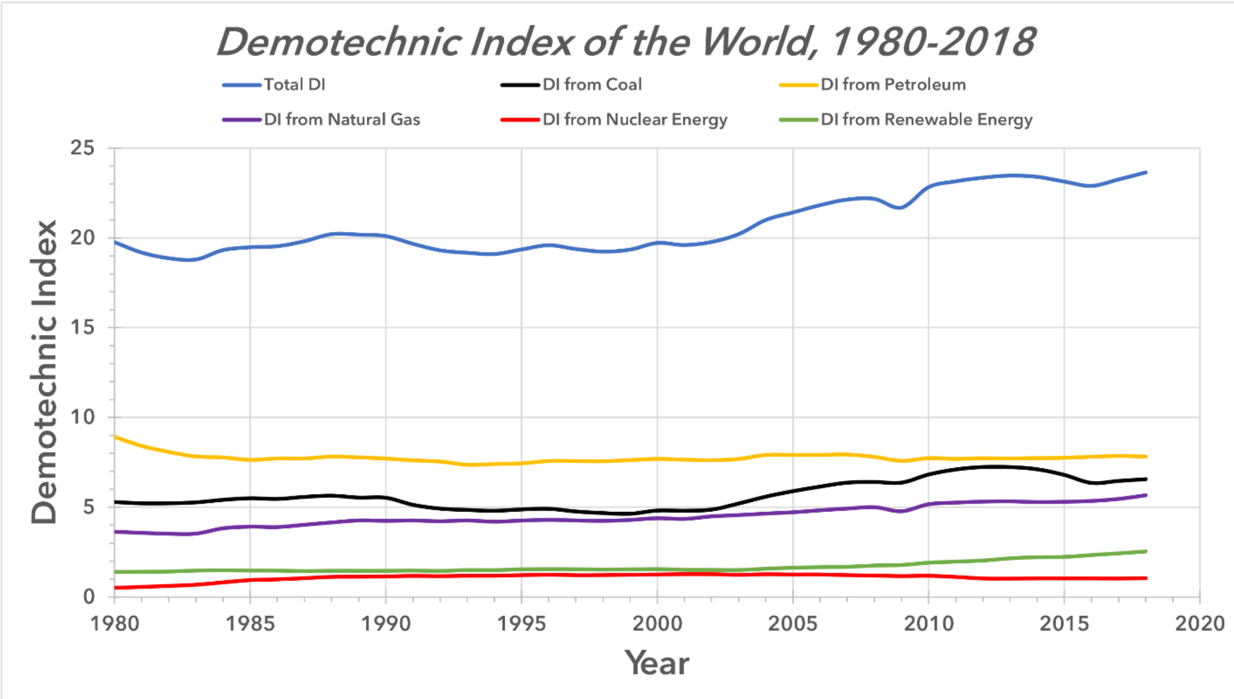

Fig. 3. *Evolution of the World Demotechnic Indices based on different energy sources from 1980-2018. The different DI series displayed are Total DI (blue), DI from Coal (black), DI from Petroleum (yellow), DI from Natural Gas (purple), DI from Nuclear Energy (red), and DI from Renewable Energy (green).*

Figure 3 illustrates global DI calculated from global energy use and the global human metabolic energy demand (blue line at top). The various energy sources and their contributions to this DI from 1980-2018 are also illustrated. During the past four decades, the overall global DI has increased (Fig. 3) from ca. 20 to ca.24. This is reasonable in that increasing populations utilize more energy, and as nations develop, their energy intensity increases, so the DI also rises.

The contributions of various energy sources to the global DI are not all monotonically increasing, however. From greatest to least, petroleum has contributed the most to the total DI, followed by coal, natural gas, renewable energy (solar power, wind, hydroelectric, geothermal, etc.), and nuclear energy. This order came as no surprise, as it was anticipated that consumption of fossil fuels (primarily petroleum) would be the largest contributor to the DI. None of the lines of these five sources cross each other in the graph, which means that the order from greatest to least DI contribution has remained the same for the last 40 years.

Overall, petroleum has seen a slight decrease from 1980 to 2018, going from 8.92 to 7.82, respectively. This is a 12% decrease, but for the most part the DI from petroleum consumption has remained stable during this timeframe.

The DI from coal has seen a slight rise from 1980 to 2018, going from 5.29 (1980) to 6.57 (2018), a 24% increase. There was a dip in coal consumption between 1990 and 2000, however this number steadily rose from 2001 to 2013, where the DI increased from 4.81 to 7.24 (50% increase). This rise can be attributed to China, who burned large amounts of coal to boost their production and economic output during this time, and in 2013 the DI from coal (7.24) nearly matched that of the DI from petroleum (7.72).

DI from natural gas steadily increased during this time span, going from 3.64 (1980) to 5.67 (2018), a 55% increase. This rise can be attributed to the energy transition that power plants around the world have made, opting to burn natural gas rather than oil. It is notable that around the turn of the century, natural gas usage nearly surpassed that of coal, but the boom in coal usage by China during that time prevented this from happening.

DI from renewable energy has seen a slight rise during this time span, going from 1.40 (1980) to 2.54 (2018), an 81% increase. This rise has come as the global scientific community has learned more about how climate change and use of fossil fuels is negatively impacting the planet and developed countries have begun to opt for renewable, green energy sources over fossil fuels. However, this transition is much easier said than done and renewable energy has a long way to go before it catches up to any of the big three fossil fuels.

Nuclear energy has played a role in aiding in this transition and has long been considered a steppingstone as countries move from consuming fossil fuels to renewable energy. This utilization of nuclear energy is displayed in Figure 3, where its DI sees a period of small growth and rises from 0.51 in 1980 to 1.27 in 2001, a 149% increase. By 2001, DI from nuclear energy has nearly caught up with renewable energy (which has a DI of 1.51 in 2001). However, nuclear power peaked in 2001, and then began a slow decline to 1.05 by 2018. Growth in renewable energy sources worldwide replaced energy production from nuclear sources.

Rank	Country	D-Index	Pop. (in thousands)
1	Gibraltar	1654.32	34
2	Qatar	212.19	2,782
3	Iceland	205.08	337
4	Singapore	195.64	5,758
5	Trinidad and Tobago	193.44	1,390
6	United Arab Emirates	144.74	9,631
7	Bahrain	138.52	1,569
8	Brunei	127.89	429
9	Canada	123.46	25,216
10	Kuwait	119.67	4,137
11	Norway	106.99	5,338
12	Wake Island (U.S. Marshall Islands)	100.53	58
13	United States Virgin Islands	97.51	105
14	Luxembourg	95.10	604
15	United States	93.11	327,096
16	Saudi Arabia	90.89	33,703
17	Malta	90.51	439
18	Turkmenistan	89.53	5,851
19	Oman	84.07	4,829
20	Faroe Islands	83.15	48
21	New Caledonia	81.88	280
22	Saint Pierre and Miquelon	76.30	6
23	South Korea	72.89	51,172
24	Australia	71.85	24,898
25	Belgium	70.25	11,482

Table 2. *Top 25 countries with the highest Demotechnic Index (DI) ratings in 2018. Island nations are highlighted in yellow. Out of the top 25 countries, 10 are island nations; they account for 40% of the top 25 countries.*

Shifting from a global perspective of the DI to a national one, Table 2 lists the top 25 countries in the 2018 Demotechnic Index. The range of DI scores between these countries is quite large; ranked #1 on this list is the country of Gibraltar with a DI of 1654.32, while the #25 country is Belgium with a DI of 70.25. To emphasize just how large Gibraltar's DI is, their score is nearly 7.8 times that of the #2 country, Qatar, who had a DI of 212.19. The rest of the top 5 countries all had DIs above 190.00. There was another large drop from #5 Trinidad and Tobago (193.44) to #6 U.A.E. (144.74), but from there the DI tends to gradually decrease.

The presence of more developed countries such as the United States, Canada, South Korea, and Australia was no surprise, however the amount of island nations (highlighted in yellow in Table 2) which appeared was unexpected. Out of the top 25 countries on the 2018 DI, ten were island nations. These countries were Trinidad and Iceland, Bahrain, Brunei, Tobago, Wake Island, the U.S. Virgin Islands, Malta, the Faroe Islands, New Caledonia, and Saint Pierre and Miquelon. These nations make up 40% of the top 25. Furthermore, a total of 30 island nations ranked in the top half of the 2018 DI, making up 25% of countries above the median, and out of these countries, only four had populations over 1 million people.

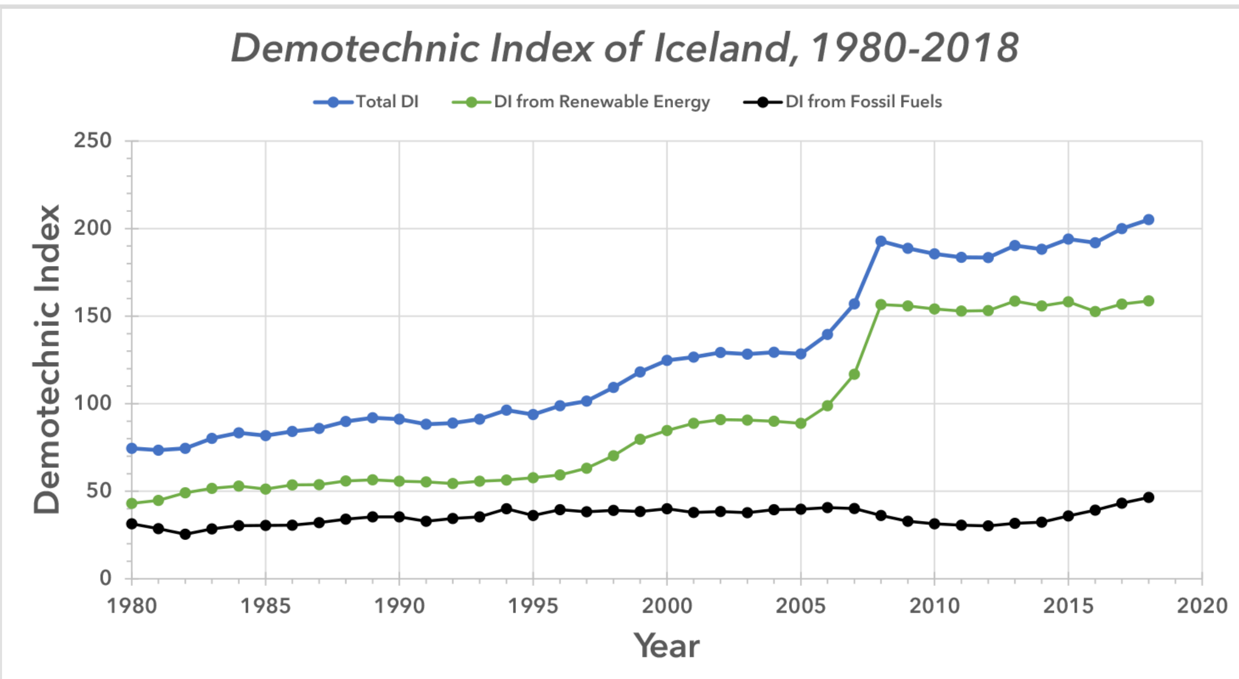

Fig. 4. Evolution of Demotechnic Index (DI) of Iceland from 1980-2018. Total DI (blue), DI from renewable energy (green), and DI from coal and petroleum (black) are all shown.

Although the DI is a metric used to understand how much energy a country's population is consuming, it can sometimes be misleading if the type of energy being used is not considered. For example, although Iceland is a country which placed 3^{rd} in the 2018 DI, a large amount of their energy comes from “green” sources (hydroelectric and geothermal).

Figure 4 shows the evolution of Iceland’s DI from 1980-2018, and includes their total DI, DI from renewable sources, and DI from fossil fuels. It is clear to see that Iceland has seen an impressive increase in energy consumption over the last four decades, as their total DI went from 74.49 in 1980 (ranked 18^{th}) to 205.08 in 2018 (ranked 3^{rd}). It is notable that the trend of this total DI is closely mirrored by the trend of Iceland’s DI for renewable energy; Iceland’s green energy saw a massive spike between the years 2005 and 2008. During this three-year span, Iceland’s green energy DI increased by over 40%, going from 88.77 (2005) to 156.64 (2008). Since 2008, Iceland’s green DI has remained stable.

On the other hand, Iceland’s DI from fossil fuels has remained stagnant for much of the last 40 years. In 1980, this number was 31.42, and although it had grown to 40.65 by 2006, the DI from fossil fuels dipped as low as 30.19 in 2012. It has since increased back to 46.43 in 2018. This insignificant amount of change in Iceland’s DI from fossil fuels shows that clearly, Iceland's total DI is much more dependent on their energy from their geothermal and renewable resources.

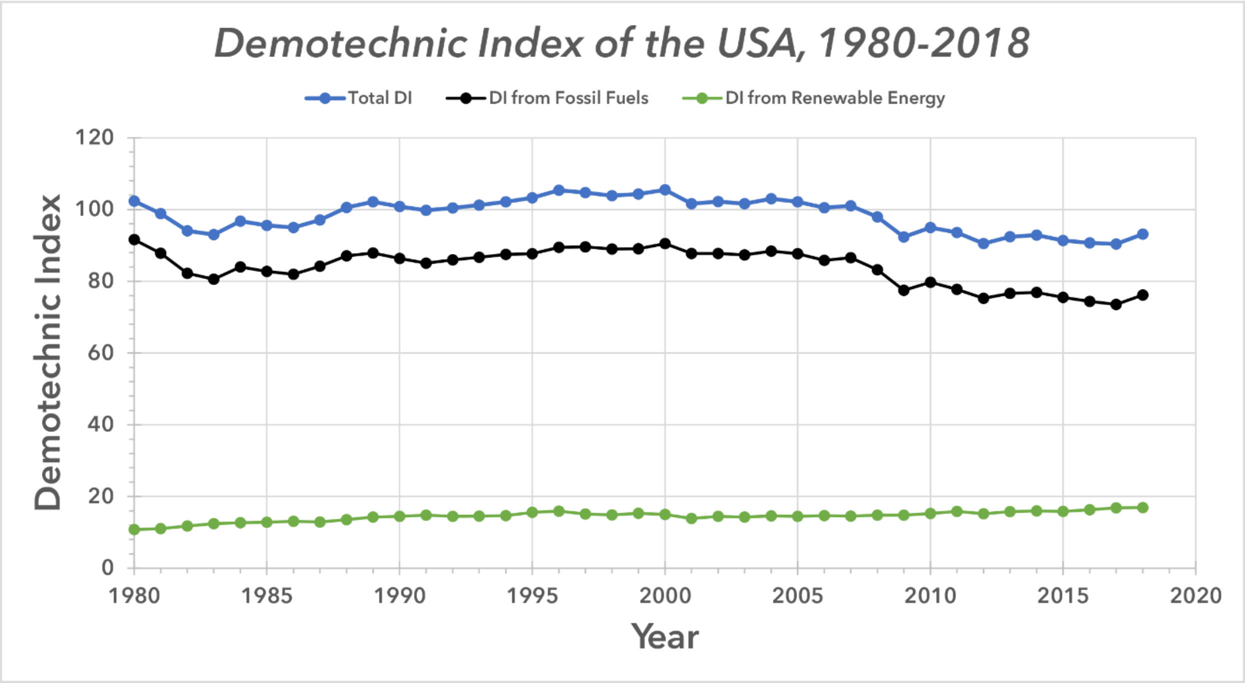

Fig. 5. *Evolution of the Demotechnic Index (DI) of the United States from 1980-2018. Total DI (blue), DI from nuclear and renewable energy (green), and DI from fossil fuels (black) are all shown.*

Compared to the total, green, and fossil fuel DIs of Iceland, the United States expectedly does not fare nearly as well from an environmentally friendly standpoint. In the case of the U.S., the roles of their fossil fuel and green DIs are reversed with Iceland's.

Figure 5 shows the evolution of the United States' DI from 1980-2018, and includes their total DI, DI from nuclear and renewable sources, and DI from fossil fuels. From 1980 to 2000, the U.S. had a generally increasing total DI which went from 102.36 to 105.48, respectively. Then, from 2000 to 2018, their DI decreased from 105.48 to 93.11, respectively, and as of 2018 DI the US ranked 16th. It is easy to see the resemblance between the changes in the U.S.'s total DI and their DI from fossil fuels – the two mirror each other's spikes and dips exactly.

In contrast, the United States' DI from green energy does not mimic the total DI in any way and maintains a gradual but minimal increase over the past 40 years, starting at 10.76 in 1980 and growing to 16.94 by 2018. This number remains torpid and makes up a small portion of the total DI, much like Iceland's DI from fossil fuels.

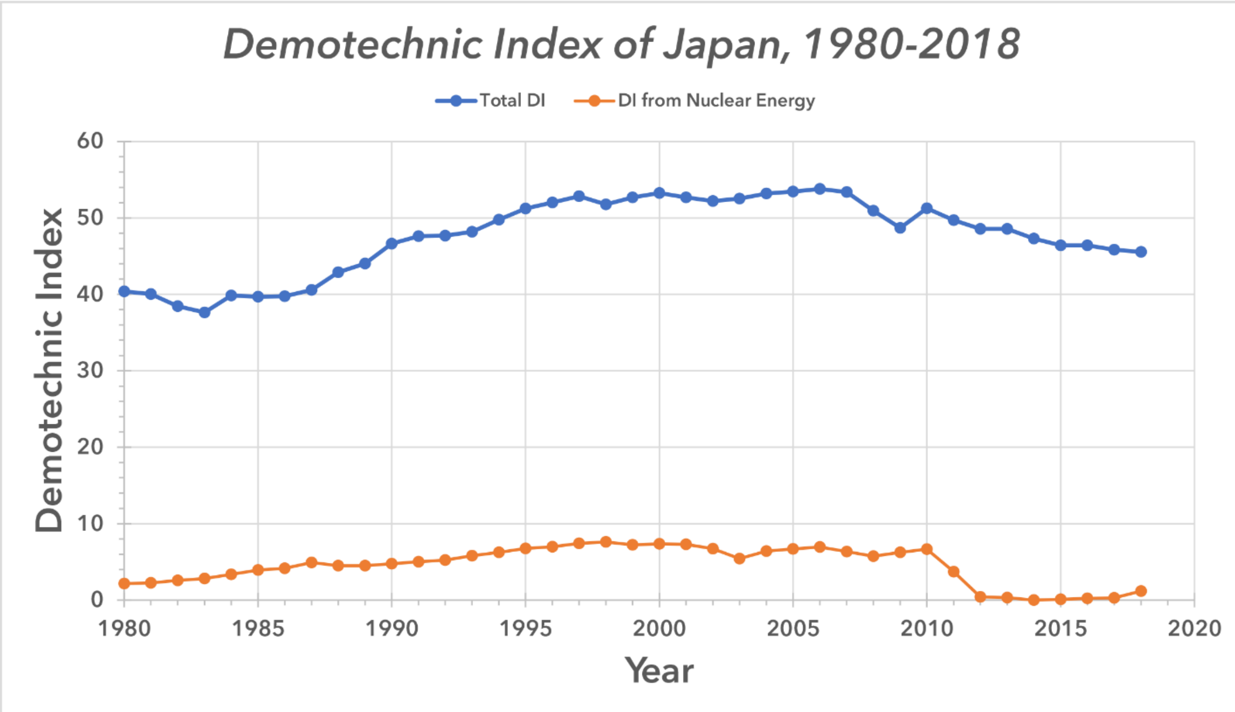

Fig. 6. Evolution of the Demotechnic Index (DI) of Japan from 1980-2018. Total DI (blue) and DI from nuclear energy (orange) are shown.

Some countries are prone to more natural disasters than others due to their geographic location in the world, and the Demotechnic Index is able to show these events because they directly cause destruction to a country's infrastructure, and therefore their ability to consume energy.

One example of this is Japan, which sits on the Ring of Fire, a region on the edges of the Pacific Ocean that is susceptible to volcanoes, earthquakes, and tsunamis due to tectonic activity. Japan most recently ranked 45th on the 2018 DI with a score of 45.55. The evolution of their total and nuclear energy DI's is shown in Figure 6, and it is visable that they maintained a steady increase in total DI from 1986 to 2006. However there are a handful of notable dips - one is in 1983, a year in which the 7.7 magnitude Sea of Japan Earthquake stuck the west coast of Japan (National Research Council 1984), and the nation's total DI hit 37.64, the lowest it has been in the last 40 years. Another is from 2007 to 2009, when the total DI decreased from 53.37 to 48.68, respectively, however this was due to the Great Recession. The last significant decrease comes after 2010, where Japan's total DI saw a steady decline over the last 8 years measured.

It is well known that Japan experienced a 9.1 magnitude earthquake and a subsequent tsunami in 2011, both of which caused substanstial damage to the country's infrastructure (Rafferty et al. 2022). Most notably, the Fukushima Daiichi nuclear power plant suffered a meltdown due to the impact of the tsunami, causing irrevesable damage to the plant, as well as the leakage of radioactive materials that had been inside the reactors (Brittanica 2021). Although the effects of this disaster do not show up as well on the plot of Japan's total DI, it is very clear when looking at Japan's DI from nuclear energy. From 2010 to 2011, Japan's nuclear DI dropped by nearly half and went from 6.66 to 3.71, respectively. This number continued to decline, and by 2014 the country's nuclear DI measured 0.00. In the aftermath of the 2011 earthquake and tsunami, Japan adopted a moratorium on nuclear energy for several years. By 2018, the nuclear DI number had risen to 1.17 once again.

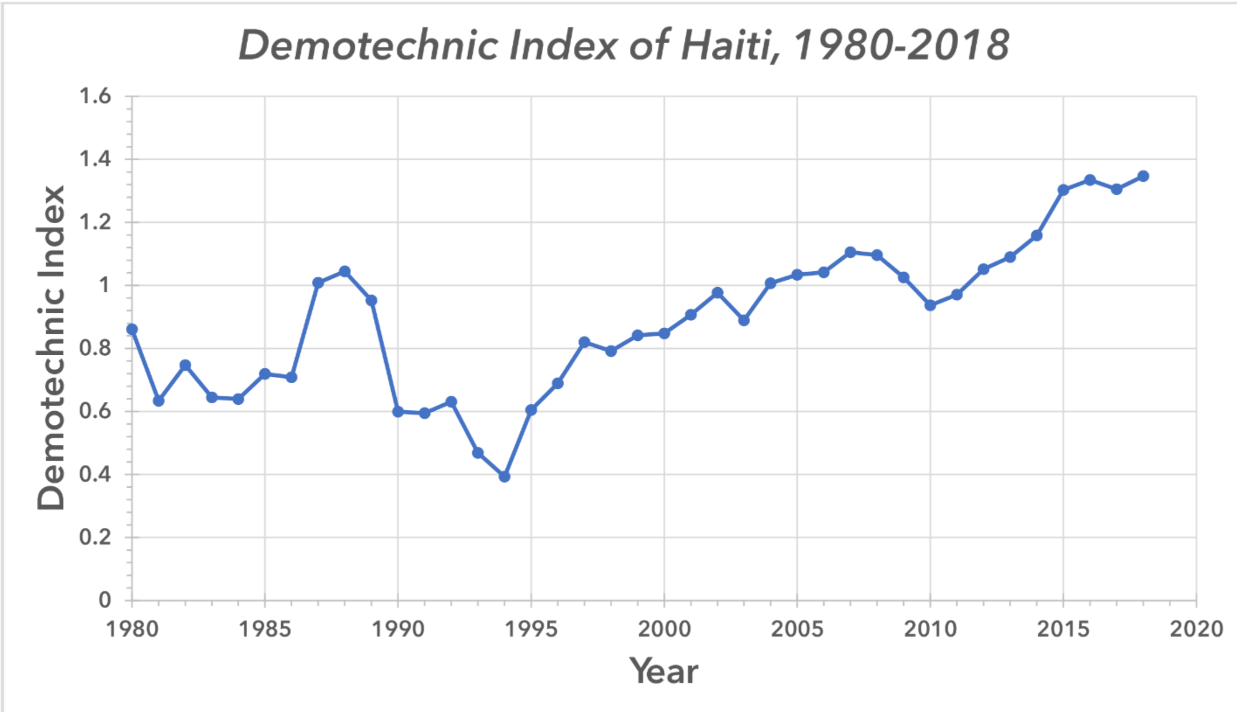

Fig. 7. *Evolution of the total Demotechnic Index (DI) of Haiti from 1980-2018.*

Another country which is predisposed to natural disasters is Haiti, which rests on an island in the Carribean Sea, and shares a border to the east with the Dominican Republic. This region of the world is known to experience hurricanes on a yearly basis, as well as occasional earthquakes.

Figure 7 shows the evolution of Haiti's total DI from 1980-2018, and it is evident that the country's DI is very volatile. Overall, Haiti has seen an increase in their DI over the last 40 years, though as of 2018 the country ranked 192nd out of 216 countries, with a DI of 1.35. Despite their progress, they have incurred some major setbacks in the way of natural disasters, and once again, the results of these setbacks appear on the DI.

The first of these disasters appears in 1994. Haiti had already been on the decline due to political corruption and civil unrest, but Hurricane Gordon caused widespread destruction which dropped Haiti's DI to 0.39 in 1994, the country's lowest point in this timeframe. Despite this catastrophe, Haiti's DI saw a fairly steady increase until 2008, when it once again took a dive due to natural disasters. In the 2008 hurricane season, Haiti was battered by four storms, one after the other. These storms were Hurricanes Fey, Gustav, Hanna, and Ike, and the combined damage these storms and the subsequent flooding caused was enough to drop Haiti's DI from 1.30 in 2008 to 1.10 in 2009.

Additionally, on January 1, 2010 Haiti was devastated by a 7.0 magnitude earthquake which hit the capital city of Port-au-Prince on the west coast of the country. Furthermore, the destruction from the earthquake caused large amount of the country's drinking water to become contaminated which resulted in an outbreak of cholera in the country (Pallardy 2022). These unfortunate circumstances caused Haiti's DI to plummet further to 0.94 in 2010. With the help of the United Nations, Haiti has since built back to a 40 year high DI of 1.35 by 2018. Nevertheless, it is only a matter of time before Haiti and its neighboring countries in the Carribean are shocked by the next natural disaster.

Rank	Country	D-Index	Pop. (in thousands)
193	Yemen	1.31	28,499
194	Togo	1.28	7,889
195	Liberia	1.17	4,819
196	Comoros	1.17	832
197	Guinea	1.17	12,414
198	The Gambia	1.08	386
199	Afghanistan	1.03	37,172
200	Tanzania	1.03	56,313
201	Eritrea	0.92	3,453
202	Mali	0.88	19,078
203	Ethiopia	0.85	109,224
204	Guinea-Bissau	0.76	1,874
205	Uganda	0.74	42,729
206	Burkina Faso	0.69	19,751
207	Madagascar	0.61	26,262
208	Sierra Leone	0.60	7,650
209	South Sudan	0.52	10,976
210	Malawi	0.49	18,143
211	Rwanda	0.48	12,302
212	Niger	0.47	22,443
213	Democratic Republic of the Congo	0.47	84,068
214	Central African Republic	0.47	4,666
215	Chad	0.27	15,478
216	Somalia	0.25	15,008
217	Burundi	0.22	11,175

Table 3. *Bottom 25 countries with the lowest Demotechnic Index (DI) ratings in 2018. African nations are highlighted in yellow. Out of the bottom 25 countries, 23 are in Africa. 74.5% of African countries place in the 25th percentile of the entire 2018 DI, and 94.5% place in the bottom 50th percentile.*

Another case study of correlation between the Demotechnic Index and a country’s geography is the low DI of countries located in Africa. It is well documented that the majority of African countries are less developed when compared to the rest of the world, and this is further supported by the DI.

Table 3 shows the bottom 25 countries (#193-216) in the 2018 DI rankings. The countries highlighted in yellow are ones located in Africa. Out of the bottom 25 countries, 23, or 92% are African nations. Furthermore, 74.5% of African nations place in the 25th percentile of the 2018 DI, and 94.5% of African nations place in the lower 50th percentile.

These statistics speak to the disparity between African nations and the rest of the globe, and much of this gap's existence can be attributed to the continent's unfortunate history of slavery, racism, colonization, corruption, and civil war.

The foregoing illustrates that the Demotechnic Index can be used to analyze countries in a historical context. Much like natural disasters, the effects of major cultural events in a country's history (such as war or political strife) are often visible when the DI of a nation is plotted.

One example of the appearance of historical events on the DI is the Arab Spring, a movement of social and political protests in East Africa and the Middle East, many of which aimed to overthrow the current government in their respective countries. These protests took place mainly between 2011 and 2013, however many countries experienced continued unrest following the Arab Spring (Chughtai 2021). The following four figures (Figures 8-11) are DI plots for Libya, Tunisia, Yemen, and Syria, all of which were greatly affected by the events of the Arab Spring. In each graph, the periods of protest are shaded in blue, while following conflict is shaded in red.

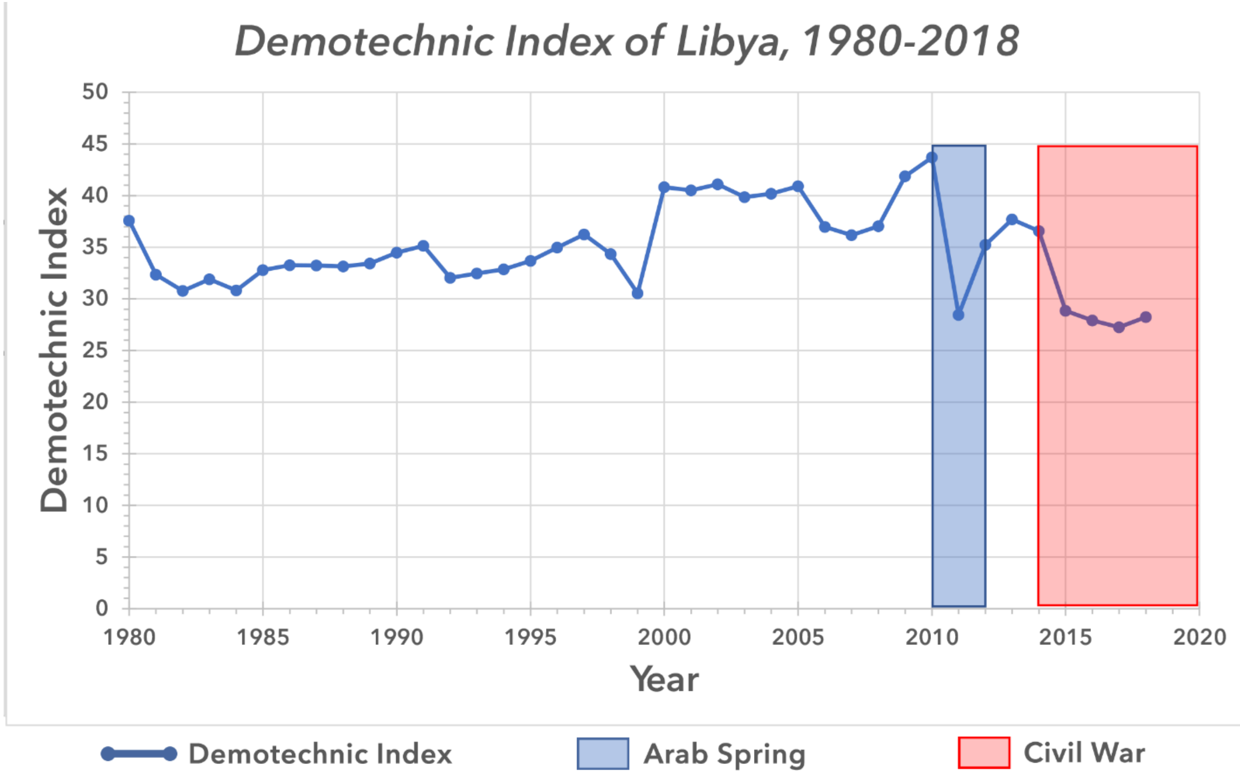

Fig. 8. *Evolution of the total Demotechnic Index (DI) (blue line) of Libya from 1980-2018. Periods of Arab Spring revolution is shaded in blue and periods of civil war are shaded in red.*

Starting with Libya (Figure 8), their protests began in 2010 and lasted until 2013. During this time, there was a massive drop in their DI score, which fell from 43.69 in 2010 to 28.45 in 2011, a drop of nearly 35%. In 2011, Libyan dictator Muammar Gaddafi was captured and executed by rebel forces (Chughtai 2021). Following Gaddafi's death, Libya's DI increased for two years, but the country was plunged into a civil war in 2014, causing Libya's DI to drop from 36.56 to 27.35 from 2014 to 2017. As of 2018, Libya had a DI of 28.23, making them the 73rd ranked country and the 2nd highest ranked African country.

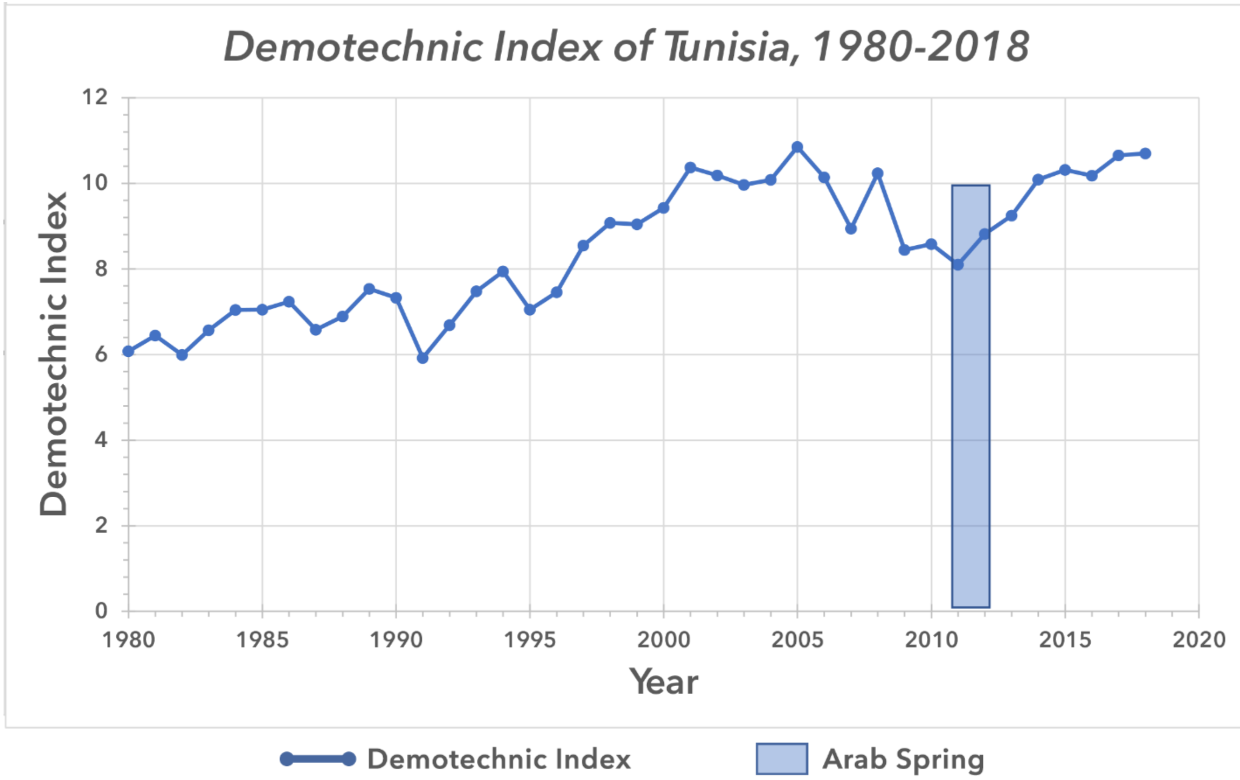

Fig. 9. *Evolution of the total Demotechnic Index (DI) (blue line) of Tunisia from 1980-2018. Periods of Arab Spring revolution is shaded in blue.*

In Tunisia (Figure 9), protests began near the end of 2010 and lasted through the beginning of 2012. Tunisia's DI dropped from 8.58 to 8.10 from 2010-2011, and in 2011, Tunisian president Zine El Abidine Ben Ali was successfully overthrown by the citizens of Tunisia (Chughtai 2021). Following this overthrow, Tunisia experienced an increase in their DI back up to 8.82 in 2012, and their DI has continued to rise since the end of their protests. It is notable that Tunisia is the only country to have shown a continued increase in DI since the Arab Spring, and in 2018 they reached a DI of 10.70, a number that had not been seen since 2005. As of 2018, Tunisia ranked 134th in the DI, making them 7th highest ranked African nation.

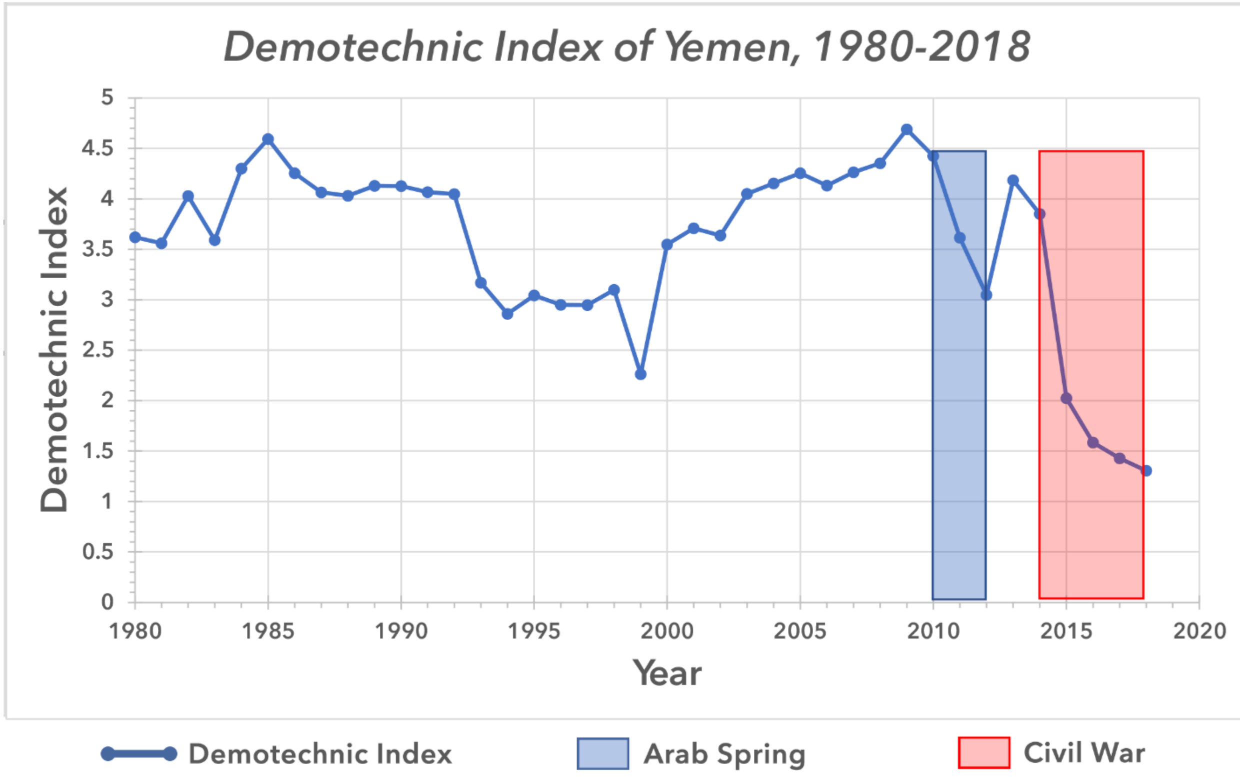

Fig. 10. *Evolution of the total Demotechnic Index (DI) (blue line) of Yemen from 1980-2018. Periods of Arab Spring revolution is shaded in blue and periods of civil war are shaded in red.*

In Yemen (Figure 10), protests began in 2010 and lasted through 2012. Between 2009 and 2012, Yemen's DI dropped from 4.69 to 3.05, a low which had not been seen since 1999 when Yemen's DI was 2.26. In 2012, protestors were able to successfully force Yemen president Ali Abdullah Saleh to resign (Chughtai 2021). Following Saleh's resignation, Yemen's DI saw an increased to 4.19 in 2013, but the country soon fell into a civil war and their DI plummeted to 1.31 in 2018, the lowest it had been in the last 40 years. The Yemeni Civil War has persisted and is still being fought in 2022. As of 2018, Yemen ranked 193rd in the DI, making them the 25th lowest country.

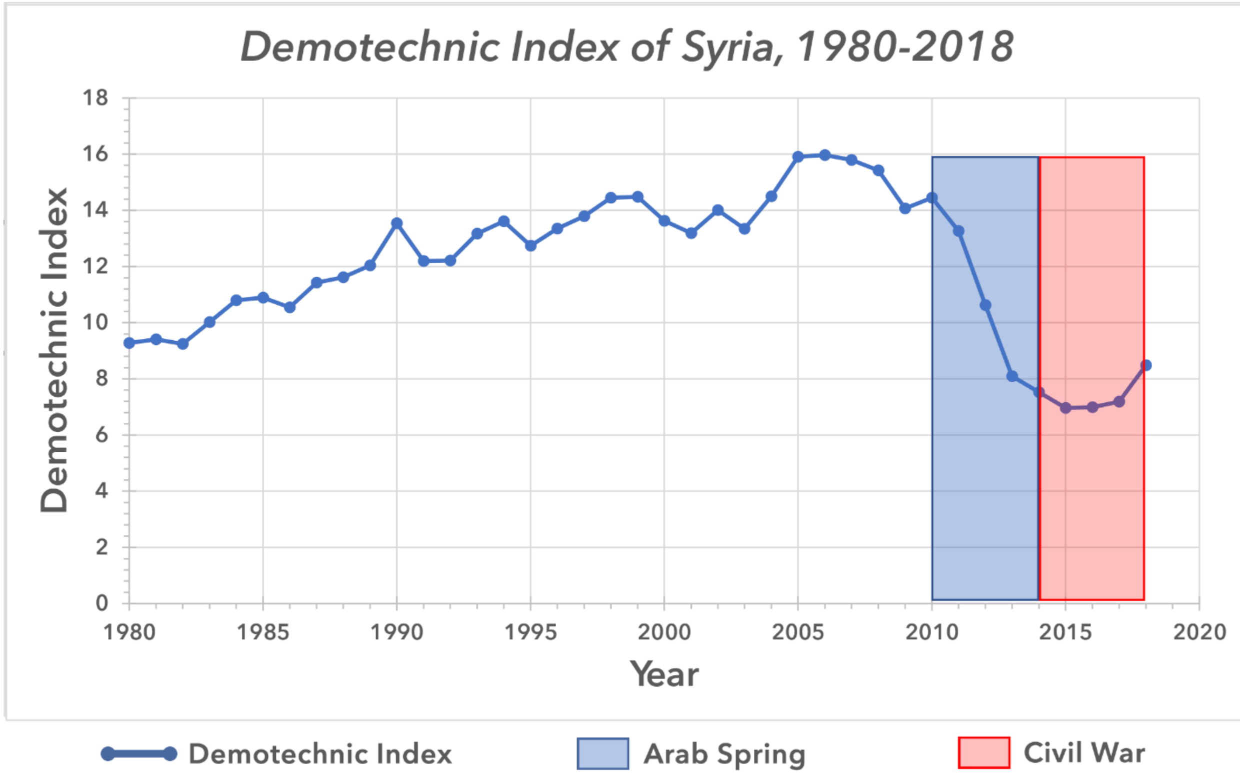

Fig. 11. *Evolution of the total Demotechnic Index (DI) (blue line) of Syria from 1980-2018. Periods of Arab Spring revolution is shaded in blue and periods of civil war are shaded in red.*

In Syria (Figure 11), the Arab Spring began in 2010 and lasted until 2014, when the government fell to terrorist groups, namely the Islamic State (IS, ISIL, ISIS), and the country has since felt continued civil war and unrest. From 2010 to 2015, Syria's DI fell by more than 50%, going from 14.45 to 6.96. From 2015 to 2016, the Syrian government received assistance from the Russian military in combatting terrorists, allowing Syria's DI to somewhat recover (Chughtai 2021). But despite their progress, the country continues to be a warzone and a breeding ground for terrorist factions, and many Syrian citizens have since fled the country as refugees. As of 2018, Syria had a DI of 8.49 in 2018, ranking them 143rd.

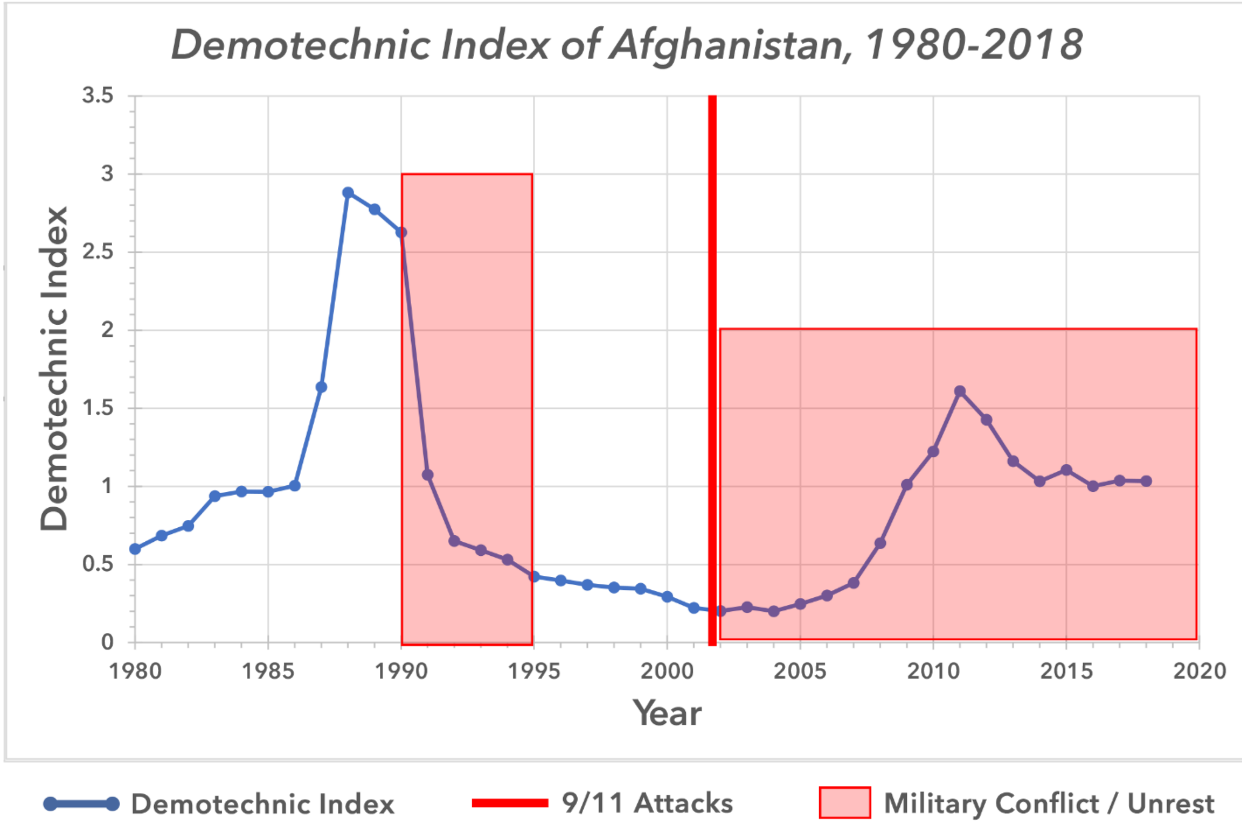

Fig. 12. *Evolution of the total Demotechnic Index (DI) (blue line) of Afghanistan. Periods of military conflict are shaded in red, and the 9/11 Attacks are marked by a red line.*

As you can see by the last two graphs, the Middle East has experienced much turbulence within the 40-year timeframe that the DI was calculated for. Armed conflicts, whether civil or international wars, have well been present in this region of the world, and one country that has heavily endured these times in recent history is Afghanistan.

Figure 12 shows the DI of Afghanistan in blue, while times of conflict or unrest are shaded in red. Examining this graph, Afghanistan saw a massive rise in their DI from 1986-1988. During these two years, their DI rose from 1.00 to 2.88, a 188% increase. This rise can be attributed to the occupation of Afghanistan by the Soviet Union, which began in 1979. The U.S.S.R. invested heavily in Afghanistan as it attempted to establish a satellite soviet republic there. During this time, Soviets constructed numerous military bases in the region during this time.

However, the U.S.S.R. left Afghanistan in 1990, just before they dissolved in 1991. This exit created a power vacuum in Afghanistan, and it was the Taliban, an Islamic terrorist group, who won this struggle and took control of the nation. This rise in power by the Taliban correlates with the first shaded area on the graph, where there is a major decline in Afghanistan's DI. From 1990 to 1995, their DI fell from 2.63 to 0.42, an 84% decrease. The Taliban remained in control of the country for the rest of the century, and by 2002, their DI reached 0.20 its lowest point on Figure 12.

On September 11, 2001, allies of the Taliban and terrorist group Al Qaeda carried out the infamous 9/11 Attacks in the United States. This attack consisted of four commercial airplanes being hijacked by members of Al Qaeda, two of which were flown into the World Trade Center in New York City, one being flown into the Pentagon in Arlington, Virginia, and the last being crashed into a field in Pennsylvania after interference from passengers on board. Following these attacks, the U.S. swiftly declared the Global War on Terror (GWOT) and invaded Afghanistan, Iraq, and Pakistan in an attempt to snuff out various terrorist groups in the region, and ultimately to seek revenge on Al Qaeda.

On Figure 12, the 9/11 Attacks are marked by the vertical red line toward the end of 2001. To the right of this line is a shaded area which signifies the 20-year U.S. military occupation in Afghanistan. As stated earlier, the Taliban was in power when this occupation began, and Afghanistan was at a low point, with nowhere to move but up. While present in the country, the U.S. was able to run the Taliban out of power, which can be seen by the increase in DI from 2002 to 2011. This was an astounding 705% increase in DI, which rose from 0.20 to 1.61.

On May 2, 2011, infamous Al Qaeda leader, Osama bin Laden, was killed by U.S. forces in the neighboring country of Pakistan, and with their revenge successfully executed, the U.S.' investments in Afghanistan began to subsequently decline. This decline is displayed during the remaining years in Figure 12, where Afghanistan's DI dropped from 1.61 (2011) to 1.03 (2018), a 36% decrease.

The U.S. did not pull its forces out of Afghanistan until 2021, and in the wake of their absence, the Taliban has taken control of the country once again. As of 2018, Afghanistan was ranked 199th in the DI, making them the 19th lowest nation.

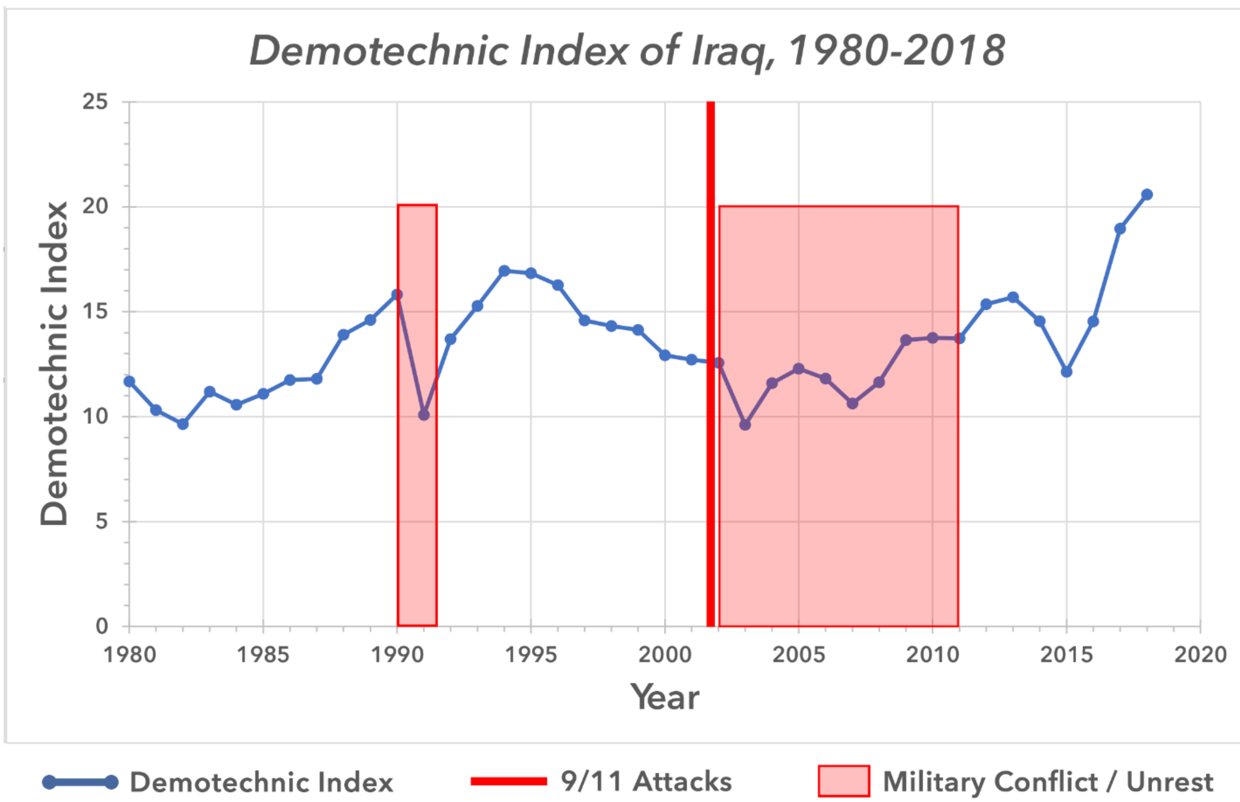

__Fig. 13.__ Evolution of the total Demotechnic Index (DI) (blue line) of Iraq. Periods of military conflict are shaded in red, and the 9/11 Attacks are marked by a red line.

Iraq possesses a similar story to Afghanistan's, having been engaged in various military conflicts throughout the last four decades, and this is reflected by their DI plot. Figure 13 shows this plot, and the first notable change in DI occurred in 1990. In this year, under the command of Iraqi president Saddam Hussein, Iraq invaded their southern neighbor Kuwait and began to destroy oil fields there in an attempt to shift the global oil market in their favor. Because of the Iraqi Invasion's implications on the global oil market, the conflict quickly garnered the attention of world powers like the United States, who allied with Kuwait, and so the U.S. deployed troops in the region, signaling the beginning of the Gulf War (1990-91). U.S. forces executed operations Desert Storm (1990-91) and Desert Shield (1991), and the Iraqi offensive was quickly extinguished. This war crippled Iraq, and Figure 13 illustrates this by a large decline in Iraq's DI from 15.81 to 10.08 in 1990 and 1991, respectively. This was a 36% decrease in DI.

Following the Gulf War, Iraq was able to build back and within a couple of years, their DI was even higher than pre-Gulf War levels. However, Hussein remained in power in Iraq, much to the disdain of the United States. As a result, U.S. Government formulated a plan to terminate Hussein, and claimed that Iraq was in possession of Weapons of Mass Destruction (WMDs) and was plotting with terrorists to use them against the United States. This, coupled with the fact that the U.S. had already begun the GWOT, gave the U.S. a motive to send troops to Iraq, which is exactly what they did in 2003, signaling the beginning of the Iraq War. This war not only led to the capture and execution of Saddam Hussein, but as with any war, much of the infrastructure of Iraq was compromised due to ground fighting and ariel attacks by U.S. Forces.

Figure 13 shows multiple declines Iraq's DI during this war, the first of which came from 2002-2003 when the U.S. initially invaded Iraq and captured Hussein. During this time, Iraq's DI fell from 12.57 to 9.61, a 23% decrease. Iraq's DI increased from 2003-2005, but fell again from 2005-2007 when it dropped from 12.29 to 10.63, a 13%

decrease. During this time, Hussein was executed. Following 2007 and with Hussein out of the picture, the U.S. installed a puppet government which gave contracts to U.S. companies to build back the infrastructure lost in the Iraq War. The U.S. pulled out of Iraq in 2011, and Iraq's DI saw growth again from 10.63 (2007) to 15.69 (2013), a 47% increase.

However, this progression was short lived, and with a crash in the global oil market in 2013, Iraq's DI crashed as well, dropping from 15.69 (2013) to 12.14 (2015), a 22% decrease. Iraq has since built back, and reached a 40-year high in 2018 with a DI of 20.51 and a ranking of 101^{st}.

DISCUSSION

Calculating the DI was sometimes challenging. One challenge was inconsistency of countries included in each of U.N. and EIA data sets. Some countries were included in the EIA energy data that were absent in the UN population data, and vice versa. To properly calculate the DI of a country, the country needed to be present in both data sets, and so because of these inconsistencies, a handful of countries were cut from the final DI list. Nevertheless, most these countries were mostly small islands, so it did not have a large impact on the final rankings. However, a handful of these countries which had been omitted were former countries, such as the former U.S.S.R, former Yugoslavia, and East and West Germany, all of which ceased to exist once the Soviet Union fell in 1991. Unfortunately, an extensive search for a reliable population dataset for these countries did not yield any results, and so they were left off the DI.

Another challenge deriving the DI was determining how to correctly combine energy and population data for countries that have possession of territories separate from their mainland. Two examples of this issue came with the Netherlands, which also has possession of the Netherlands Antilles, the islands of Bonaire, Saint Eustatius and Saba, Curaçao, and Saint Maarten (Dutch part). Similarly, France, has possession of the Wallis and Futuna Islands and Saint Martin (French part). To make the data consistent while calculating the DI, the energy and population data from these territories were added to that of their primary nation. Thus, population and energy data of these territorial possessions was accounted with the DI of the primary nation.

A final challenge was that some nations were listed under obsolete names in the EIA and UN data sets. For example, some EIA referred to Myanmar as Burma. Despite these complications, the datasets were reconciled, and as a result a nearly four-decade trajectory of the DI was calculated for most U.N. member states.

The Demotechnic Index was initially designed to correlate a country's population with its energy consumption and synthesize the two variables to create a new metric that would reveal the ways in which populations consumed energy differently (Mata et al. 2012). However, the DI is also valuable due to the stories it can tell of a nation's past, present, and future, through an environmental, geographical, historical, and or cultural lens.

To demonstrate one of the ways in which the DI follows geographic patterns, Table 2 showed that many small island nations tend to earn surprisingly DI's, with 40% of the countries in the top 25 nations of the 2018 DI being islands. Furthermore, 28% of the upper 50^{th} percentile was made up of island nations, and 86% of these countries did not have a population of over 1 million people. These were unexpected results, but when considering the ways in which these countries consume energy and the lifestyles of the citizens who live there, it makes sense that they would place this highly on the DI. Due to their extremely limited territory, islands tend to be naturally lower in resources – even if there is some amount of valuable natural assets to be extracted and used, islands are at a disadvantage because they do not possess an adequate amount of land for their energy resources to allow them to be self-sufficient. Therefore, these countries must rely on obtaining energy sources from others, and this most often ends up being coal, petroleum, or natural gas. These fuels are often used to run generators which produce electricity, albeit at a more than likely inefficient rate, and therefore more energy is consumed than is needed.

This inefficient means of energy production, is exacerbated by the fact that many of these island countries serve as tourist destinations. This is because the lifestyles of vacationers tend be ones of luxurious excess, even if only for a short time. Obviously, not everyone on islands lives like this; citizens of islands nations largely live normal lives, and many have service jobs in the tourism industry to tend to visitors. Regardless of how excessive tourists' lifestyles are while on an island, tourism is an essential part of these countries' economies.

One last reason why islands might tend to have larger DIs than expected is because many serve as military bases for global superpowers like the United States. One such example is Wake Island, which is claimed as part of the U.S. Marshall Islands in Oceania and placed 12th on the 2018 DI. Wake Island is home to a U.S. Air Force Base and is used as a refueling point for military aircrafts (Brittanica 2019). Because of this utility, generators are used to produce large amounts of energy to power military technology and accommodations for soldiers, as well as fuel for various aircraft, vehicles, and ships.

All these sizeable and inefficient means of technological consumption by island nations, coupled with the fact that they have tiny populations which are factored into the total metabolic energy consumption in the DI equation, ultimately result in many islands placing shockingly high on the DI. From an energy usage standpoint, island living simply is not an efficient lifestyle.

Another example of how geography affects a country's DI can be seen in the case of Iceland. They placed 3rd on the 2018 DI and displayed a large amount of growth over the last 40 years. Much of this growth can be attributed to their rise in renewable energy, namely hydro and geothermal sources. Currently, about 75% of Iceland's primary energy production is from hydropower, and another 25% is from geothermal energy, making Iceland the only country with nearly 100% renewable energy production (Iceland Ministry of the Environment, Energy, and Climate). With the current climate crisis and pressure for governments to switch toward green energy source, this is a number most countries can only dream to achieve by the end of the century, much less have already achieved.

Iceland's ideal geography is what allows it to utilize these energy sources; its location sits near geothermal hot zones under the earth's crust which produce volcanoes and heat up water, allowing for easy electricity production. The country is also surrounded by water and possesses many rivers, making it incredibly easy to harvest hydroelectric power. So, although Iceland has a very high DI, since nearly all their energy consumption comes from renewable, eco-friendly sources, their high energy usage bears no real consequences. Iceland has serves as a pioneer in the context of energy production and consumption and developed nations who have the means to grow their renewable energy sector should look to them as a modern blueprint to emulate.

Iceland is an example of how a country's geography can positively impact its DI, but Japan and Haiti are examples of the opposite. Both are prone to experience earthquakes, tsunamis, and typhoons. Haiti's DI showed how time and time again, the country has been crippled by natural disasters, many times with the effects of separate events compounding on each other. Japan is a stable country in the 75th percentile of the DI, but even their DI illustrates where they have experienced natural disasters, and even 8 years after the Fukushima Nuclear Disaster following the 2011 earthquake, Japan's nuclear sector had barely recovered.

Furthermore, due to the current climate crisis, hurricanes are becoming increasingly more common occurrences, in addition to becoming more intense storms. This means that in the future, we should expect to see even more devastation, loss of life and infrastructure, and volatile DIs in countries such as Haiti and Japan. If this is to be stopped, climate change needs to continue to be actively combatted, and this starts with the energy sources we consume.

Shifting to viewing the DI through a historical lens, by analyzing the 2018 DI map, it was plainly evident that Africa consisted of some of the lowest DIs in the world, and this was further supported by the fact that nearly all of Africa was below the median DI in 2018. Africa has long been considered an impoverished and war-torn continent, but how did it get this way? After all, it is not as if Africa does not possess vast natural resources such as aluminum, zinc, copper, and cobalt, not to mention oil, coal, gold, and diamonds (Staff, A. J. 2022).

The answer to this question lies in Africa's history of colonization. Fueled by greed for raw materials, and citing eugenics to justify their heinous acts, European powers like Great Britain, France, Germany, and Spain began the colonization of Africa around 1800. During this time, European countries went into African countries and conquered them politically, taking over their economies and forcing Africans to work for low wages harvesting natural resources. These resources were given to colonist countries, in one-sided trade contracts. In return, these countries received the protection and stability of their colonists. Often, Africans did not want to work for European profit, but Europeans implemented punitive laws and taxes which forced them to work in mines so they could pay these taxes (Ocheni et al. 2012).

These conditions, which persisted until the 1960's, constructed an Africa that was dependent on their colonist countries. So, when colonists finally left and Africans gained their independence, they were left with a watered-down cultural identity, much less natural resources for their own use, and a power vacuum that has since lead to strife across the entire continent. It is the reason why there are warlords fighting for dominance in Central Africa, pirates and criminals that patrol the waters in costal African nations, and leaders who remain in office until a revolution happens, are all present 50 years after colonialism in Africa ended.

One such revolution was the Arab Spring, an event which saw the overthrow and or execution of multiple rulers in Northern Africa and the Middle East. Many of these revolutions were large enough to chart on the DI, and though many of them involved protesting which gave way to riots and violence in the streets, some countries like Tunisia saw an upward trends after a change in leadership. On the other hand, other countries such as Syria and Yemen have only seen more conflict, and either engaged in civil war or were overrun by terrorist groups like ISIS, the Taliban, and Al Qaeda.

It is terrorist groups such as these and their wicked actions like the 9/11 Attacks which inspired the global powers like the United States to wage the GWOT in the Middle East at the beginning of the 21st century. Wars in Afghanistan and Iraq saw the U.S. take back control of the region from terrorists, but only after extensive aircraft bombings and drone strikes that decimated whole cities in these countries, not to mention killed hundreds of thousands of innocent Afghan and Iraqi civilians.

If these countries were not already at rock bottom after terrorist rule, this destruction of infrastructure lead them there, and it is at the beginning of both the War in Afghanistan and the Iraq War that these countries see lowest points in their DI. This is because if there is less infrastructure, there is less electricity being produced, and therefore less energy being consumed.

After these initial low points, Afghanistan and Iraq both saw rises in their DI as the United States installed puppet leaders in these countries made shrewd contracts which allowed U.S. companies to handle the rebuild of infrastructure. In other words, the U.S. was largely responsible for the destruction and reconstruction of these countries, and they profited the entire time, albeit at the expense of the lives of innocents and American soldiers.

By the time the United States had pulled out of Iraq in 2011, to many Americans it seemed like a senseless, selfish war that was only fought to take out an opposing political figure and utilized fabrications of WMDs to justify itself. Similarly, in August of 2021, within days of the last American soldiers coming home from Afghanistan, the Taliban regained control of the country and declared the war a victory. This left many Americans stumped as to why their country had remained in the region for 20 years, only to relegate power to the enemy by the end; the whole war seemed pointless. Despite public opinion on the war, Iraq's DI has trended upward post-war, and so long as there is peace in the region, they look to continue this growth. On the other hand, Afghanistan's DI will inevitably decline due to the Taliban takeover, much like it did when the U.S.S.R. left the country in 1990.

CONCLUSION

Since its inception in 1982, The Demotechnic Index is a metric that has mostly been forgotten by science, but there is a vast amount of cultural, geographic, environmental, and historical knowledge that can be learned through studying the data it shows on both a global and national scale.

The DI illustrates the tangible, energy-related consequences of human actions, and for better or for worse, these consequences affect the differing standards of living that people all around the world experience. Technological energy breakthroughs and inventions can elevate nations to new heights, as seen in Iceland. By contrast, wars can devastate whole populations and foster the exploitation of nations for years.

The DI also reveals the ways in which we interact with the natural world around us. This can be seen by the sources of energy we choose to consume and the effects they have on environment, or in the natural disasters that ruin countries much in the same way wars can.

With the world today facing so many challenges, such as the current climate crisis, the global Covid-19 Pandemic, and a fresh, delicate, war as the Ukraine defends their turf from a Russian offensive, it is now more crucial than ever that humanity understands the consequences of our actions before we take them and how we can more intelligently interact with the world we live in. Though these challenges are incredibly daunting, we have the tools, science, and technology to help us make better informed decisions in the future, and the Demotechnic Index is just one of these valuable instruments.

REFERENCES CITED

Australian Health Survey. 2013. Australian Health Survey: Physical Activity, 2011-12. Australian Bureau of Statistics Catalog # 4364.0.55.004. [Online]. Accessed 09 June 2021. http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/D4495467B7F7EB01CA257BAC0015F593

Britannica, T. Editors of Encyclopaedia (2021, July 26). Fukushima accident. Encyclopedia Britannica. https://www.britannica.com/event/Fukushima-accident

Britannica, T. Editors of Encyclopaedia (2019, March 1). Wake Island. Encyclopedia Britannica. https://www.britannica.com/place/Wake-Island-Pacific-Ocean

Cavill, N., Kahlmeier, S., and Racioppi, F. (eds.). 2006. Physical activity and health in Europe: Evidence for action. World Health Organization. Copenhagen. [Online]. Accessed 09 June 2021. http://www.euro.who.int/__data/assets/pdf_file/0011/87545/E89490.pdf

Chughtai, A. (2021, January 14). Timeline: How the Arab Spring unfolded. Al Jazeera. https://www.aljazeera.com/news/2021/1/14/arab-spring-ten-years-on

DHHS-USDA. 2015. 2015–2020 Dietary Guidelines for Americans. 8th Edition. Appendix 7. Nutritional Goals for Age-Sex Groups Based on Dietary Reference Intakes and Dietary Guidelines Recommendation December 2015. U.S. Department of Health and Human Services and U.S. Department of Agriculture. Washington, DC. [Online]. Accessed 09 June 2021. https://health.gov/dietaryguidelines/2015/resources/2015-2020_Dietary_Guidelines.pdf

Ehrlich, Paul R. 1968. The Population Bomb. New York: Ballantine Books.

FAO Statistics Division. 2008. FAO Methodology for the measurement of food deprivation: Updating the minimum dietary energy requirements. Food and Agriculture Organization of the United Nations. Rome. [Online]. Accessed 09 June 2021. http://www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/metadata/undern ourishment_methodology.pdf

Gibraltar, 2014. Gibraltar national energy efficiency plan. HM Government of Gibraltar, 36p. https://www.gibraltar.gov.gi/new/sites/default/files/HMGoG_Documents/National_Energy_Efficiency_Action_Plan.pdf

Hardin, G. (1968). The Tragedy of the Commons. Science, 162(3859), 1243–1248. http://www.jstor.org/stable/1724745

Mata, F. J., Onisto, L. J., & Vallentyne, J. R. (2012). Consumption: the other side of population for development. Ethics in Science and Environmental Politics, 12, 15–20.

Ministry of the Environment, Energy, and Climate - Energy. Government of Iceland. (n.d.). Retrieved March 30, 2022, from https://www.government.is/topics/business-and-industry/energy/

National Research Council. 1984. Japan Sea Central Region Tsunami of May 26, 1983: A Reconnaissance Report. Washington, DC: The National Academies Press.https://doi.org/10.17226/18402.

NHMRC. 2015. Nutrient reference values for Australia and New Zealand including recommended dietary intakes. National Health and Medical Research Council. Department of 36 Health and Ageing of the Australian Government. [Online]. Accessed 09 June 2021. https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/n35.pdf.

Ocheni, S., & Nwankwo, B. C. (2012). Analysis of Colonialism and Its Impact in Africa. Cross Cultural Communication, 8(3), 46–54. https://doi.org/:10.3968/j.ccc.1923670020120803.1189

Pallardy, R. (2022, January 5). 2010 Haiti earthquake. Encyclopedia Britannica. https://www.britannica.com/event/2010-Haiti-earthquake

Périssé, J. 1981. Energy and protein requirements: Past work and future prospects at the international level. Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements. Information Paper No. 1. Food and Agriculture Organization of the United Nations. Rome. [Online] Accessed 07 June 2021. http://www.fao.org/docrep/MEETING/004/M2995E/M2995E00.HTM

Rafferty, J. P. and Pletcher, . Kenneth (2022, March 4). Japan earthquake and tsunami of 2011. Encyclopedia Britannica. https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011

Scientific Committee for Food. 1992. Nutrient and energy intakes for the European Community. Reports of the Scientific Committee for Food (Thirty-first series), opinion expressed on 11 December 1992. [Online]. Accessed 09 June 2021. http://ec.europa.eu/food/fs/sc/scf/out89.pdf.

Staff, A. J. (2022, February 15). Mapping Africa's Natural Resources. Maps News | Al Jazeera. Retrieved March 30, 2022, from https://www.aljazeera.com/news/2018/2/20/mapping-africas-natural-resources

Timeline: Haiti's history and current crisis, explained. Concern Worldwide. (2021, December 23). Retrieved March 24, 2022, from https://www.concernusa.org/story/timeline-haiti-history/

United Nations. (2019). World Population Prospects. United Nations. Retrieved April 7, 2022, from https://population.un.org/wpp/

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. International - U.S. Energy Information Administration (EIA). (n.d.). https://www.eia.gov/international/data/world

APPENDICES

Appendices are included as a supplemental data that includes multiple spreadsheet workbooks, as well as a PDF table and PNG map.

APPENDIX 1

US EIA International Energy Con	EIA energy data for every country and every energy source from 1980-2018 in billions of BTU
Total Energy	Sum of energy from coal, natural gas, petroleum, nuclear, and total renewable energy in billions of BTU
Coal	EIA energy data for coal in billions of BTU
Natural Gas	EIA energy data for natural gas in billions of BTU
Petroleum & Other Liquids	EIA energy data for petroleum & other liquids in billions of BTU
Nuc, Renew, & Other (Total)	Sum of energy from nuclear and total renewable energy in billions of BTU
Nuclear	EIA energy data for nuclear energy in billions of BTU
Renewables & Other	EIA energy data for renewable energy and other sources in billions of BTU

APPENDIX 2

Population	National populations from 1980-2018 (in thousands) from the United Nations
Total Metabolic Energy (kJ)	Calculated human metabolic energy demand per year (kJ/year) for countries, 1980-2018

APPENDIX 3

EIA International Energy (BTU)	EIA energy data for every country and every energy source from 1980-2018 in billions of BTU
Total Energy (Joules, DI Order)	Calculated total energy consumption in joules (J) for countries, 1980-2018
DI	Calculated Demotechnic Index for countries, 1980-2018

APPENIDX 4

Table of the complete 2018 DI rankings for 216 countries. Includes each country's name, rank, DI, and population (in thousands).

APPENDIX 5

Full resolution PNG of the global map (Fig. 2) of the Demotechnic Index for all nations in 2018. Countries are colored according to where their DI falls along a gradient scale, which follows the distribution of DI scores.