The Lead Education and Abatement Design Group
Working to eliminate lead poisoning globally and to protect the environment from lead in all its uses: past, current and new uses
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Leaded Vehicular Fuel and the Global Effort to Eliminate Lead Poisoning:

Factors constraining the global endeavour to eliminate lead additives from vehicular fuel

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Executive Summary

Airborne lead is a cumulative neurotoxin which adversely affects the function of many human biological systems. Research has demonstrated that the highly dispersive nature of leaded petrol use means that '[l]eaded gasoline causes more widespread human exposure to lead than any other single source' (Alliance to End Childhood Lead Poisoning 1999: 2). Consequently, '[t]he phasing out of lead from gasoline is considered to be a critical step in reducing population blood lead concentrations' (Wilson and Horrocks 2008: 1).

As of January 2011, the United Nations Environment Programme's Partnership for Clean Fuels and Vehicles (UNEP PCFV) reported that lead has been eliminated from vehicular fuel in all but six countries. Of these countries, only Algeria has set a target phase-out date (2013) for the elimination of leaded vehicular fuel in its markets (UNEP PCFV 2011: 7).

In order to contribute to an understanding of which factors are acting as barriers to the global effort to eliminate lead additives from vehicular fuel, this paper considers the effect of a range of potential determinants of environmental policymaking and implementation across a large number of countries with specific reference to the global effort to eliminate lead additives from vehicular fuel.

Relying on indexes compiled by various international organisations, this study considers the following variables as potential barriers to the global effort to eliminate lead additives from vehicular fuel:

- Corruption;
- Democracy;
- Press freedom;
- Per capita gross domestic product;
- Economic freedom;
- Human development levels; and
- Peacefulness levels

The study indicates high levels of correlation between continuing use of leaded vehicular fuel and levels of democracy, levels of corruption, levels of press freedom, levels of economic freedom and levels of peacefulness. While the absence of comparable time series data precludes a definitive determination of whether observed relationships between isolated determinants of environmental policy and the elimination of lead additives to vehicular fuel are causative in nature or simply highly correlative, it is possible to determine that these relationships did not emerge by chance, and that these relationships are of substantial practical effect. Read in light of the wider body of literature, these results provide strong support for the proposition that failures to

address the high levels of corruption and low levels of democracy, press freedom, economic freedom and peacefulness present in countries reliant on lead additives to vehicular fuel may be inhibiting the global effort to eliminate lead additives from vehicular fuel.

The absence of correlations between per capita GDP values, human development levels and a country's status in relation to the elimination of leaded vehicular fuel made it possible to state with confidence that neither per capita GDP values nor human development levels are causally related to a country's capacity to eliminate leaded petrol. Consequently, neither per capita GDP values nor human development levels can be considered barriers to the global effort to eliminate lead additives from vehicular fuel.

Directions for future research include analyses of comparable time series data, which would enable definitive determinations of causality to be made in relation to the correlations observed between various determinants of environmental policy and the global effort to eliminate lead additives from vehicular fuel. Further study could also employ multiple regression analysis methodologies in order to measure the relative impacts of each determinant on the elimination of leaded vehicular fuel.

Contents

Background

Lead is a cumulative neurotoxin with serious negative impacts on the human nervous, circulatory, reproductive, renal and digestive systems. Exposure to lead has been linked to disruptions to human cognitive, developmental, muscular, cardiovascular, behavioural and sensory functions; in more serious cases, lead exposure can result in death.

The Lead Education and Abatement Design Group (The LEAD Group Inc.), is a not-for-profit community organisation which develops and provides information, advice and referrals in relation to the management and prevention of lead poisoning and lead contamination. The LEAD Group Inc. is a registered Environmental Organisation and Health Promotion Charity. Established in 1991, The LEAD Group Inc. receives funding from the Australian Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), to run the Global Lead Advice and Support Service (GLASS), and is an active advocate for the elimination of lead from industrial processes and consumer products in both domestic and international markets and for the safe management of lead wherever it remains in commerce or has already caused contamination.

As recognition of the harmful health effects arising from exposure to lead has become more widespread, global efforts to eliminate lead and lead products from industry and consumables have become increasingly co-ordinated. According to the *United* Nations Environment Programme, although humans can absorb lead through either ingestion or inhalation, inhaled lead particles are more dangerous due to their greater ability to enter the blood stream (2008a: 5). Research has demonstrated that the highly dispersive nature of leaded petrol use means that '[l]eaded gasoline causes more widespread human exposure to lead than any other single source' (Alliance to End Childhood Lead Poisoning 1999: 2). Consequently, '[t]he phasing out of lead from gasoline is considered to be a critical step in reducing population blood lead concentrations' (Wilson and Horrocks 2008: 1).

As of January 2011, the United Nations Environment Programme's Partnership for Clean Fuels and Vehicles (UNEP PCFV) reported that lead has been eliminated from vehicular fuel in all but six countries. The Islamic Republic of Afghanistan (Afghanistan), the Union of Burma (Myanmar) and the Democratic People's Republic of Korea (North Korea) continue to rely solely on leaded vehicular fuel, while the People's Democratic Republic of Algeria (Algeria), the Republic of Yemen (Yemen) and the Republic of Iraq (Iraq) utilise a combination of leaded and unleaded fuel. Of these countries, only Algeria has set a target phase-out date (2013) for the elimination of leaded vehicular fuel in its markets (UNEP PCFV 2011: 7).

In 2007, Jale Tosun (currently a researcher with the University of Konstanz, Germany) conducted research for The LEAD Group Inc. examining whether international factors affect national decisions to phase out lead additives from vehicular fuel. At this time, 27 countries were reported to still utilise leaded vehicular fuel (O'Brien 2007). More than three years on, and with only six remaining countries on the leaded vehicular fuel focus list, The LEAD Group Inc. is looking to clarify which factors are constraining change in the global effort to eliminate lead additives from vehicular fuel. The constraining factors identified in this research may then be The LEAD Group Inc.'s most important contribution to its involvement in other global phase-out campaigns. These constraining factors, if also found to exist in relevant countries, may be able to be taken in to account and possibly overcome within a reasonable timeframe, in other current global toxic chemical management efforts to, for instance, eliminate lead in paints (UNEP GAELP 2010), mercury in dental (amalgam) fillings (Consumers for Dental Choice: 2011), etc.

Research Objectives

An existing body of environmental literature purports to have identified a number of factors which act as determinants of national environmental performance. These factors emerge in a number of spheres: economic (Grossman and Krueger 1995; Harbaugh et al., 2002), socioeconomic (United Nations Environment Programme 2010), cultural (Husted 2005), political (Torras and Boyce 1998), institutional (Pellegrini and Gerlagh 2006) and regulatory (Esty and Porter 2005).

However, as observed by Esty and Porter, there is an absence, in the literature, of studies that examine 'a large number of countries (including both developed and developing countries) across a broad spectrum of possible policy determinants' (2005: 392). This study aims to address this gap in the literature with specific reference to the global effort to eliminate lead additives from vehicular fuel.

This paper will consider the effect of a range of potential determinants across a large number of countries. The study will seek to identify relationships between failures to eliminate lead additives from vehicular fuel in countries still reliant on leaded petrol and the possible determinants of environmental change.

Due to the breadth of the study and range of factors to be considered, it will not be possible to develop a comprehensive analytical framework for the determination of the size of the effect of any one potential determinant of a country's ability to eliminate leaded petrol. This study does not attempt to quantify the impact of identified determinants on a country's capacity to eliminate lead additive from its vehicular fuel. Rather, this study aims to identify whether or not relationships exist between the proposed determinants of social change and a country's status in relation to the elimination of lead additives from their vehicular fuel. This study will be conducted with a view to developing foundational understanding of the factors hindering the global effort to eliminate lead additives from vehicular fuel by inhibiting change in countries which continue to rely on leaded petrol.

Methodology

Phase One: Background Research – Framework and Structural Development

Phase One of the research process entailed a foundational literature review into the mechanics of change, focusing on environmental reform on national scales. This research was undertaken with a view to the development of a list of factors which have been shown to either encourage or inhibit environmental reform in domestic contexts, considering both domestic and international factors. Initial literature trawls indicated that these factors would include political, social, economic and civil society indicators.

The factors identified in this stage of the research project were compiled to act as 'red light indicators' in the content-specific research that was to be undertaken in later phases of the project, assisting in the categorisation of data that content-specific research uncovered. With the factors identified in this phase of research acting as a foundational framework, it became possible to identify the potential factors at work inhibiting and/or encouraging change in the case studies of the remaining leaded countries.

A key concern in this stage of the research project was ensuring that the framework developed through reference to existing environmental reform literature informed the later phases of the research project, but did not act to blind the research to operative factors influencing decisions to decline to phase out leaded vehicular fuel that did not appear in generalised theories of environmental change.

Phase Two: Case Study Analysis and Extrapolation of Common Operative Factors

This phase of research involved a process of cross-referencing political, cultural, social, economic and civil society characteristics of each of the countries still reliant on leaded fuel in an attempt to extrapolate potential determinants of lead status. This process of cross-referencing analyses aimed to counter the risk (identified above) that a reliance on generalised literature relating to factors influencing environmental reform would fail to identify operative factors that might act to inhibit the phase out of lead additives from vehicular fuel in the countries in question.

By drawing out commonalities between the six countries still reliant on leaded fuel across the political, cultural, social and economic spheres, additional factors which potentially inhibited the decision to eliminate lead additive from vehicular fuel were identified. These factors were then added to the list of potential operative factors about which data needed to be collected for consideration in the data-analysis phase of the research.

Phase Three: Data Collection

Due to resource limitations associated with this research, this study did not include any firsthand data collection. Instead, indexes compiled by international organisations were used. Indexes were selected on the basis of their validity in terms of the extent to which the dataset related to the factor which had been isolated for testing (e.g. for the testing of 'corruption', the 'Corruptions Perceptions Index' compiled by *Transparency International* was relied upon). In order to maximise the accuracy of the data, only indexes prepared by independent, credible institutions were utilised in this study. Where possible, indexes recognised by or affiliated with the United Nations (and/or its representatives e.g. former Secretary-General Kofi Annan) were used. Indexes were also selected on the basis of the regularity with which they were compiled (annual indexes being the preferred interval), and the period of time for which the index had been published (in order to investigate whether identified relationships continued to operate over a period of time, it was desirable that multiple editions of the indexes had been published between 2006 and 2010).

The indexes ultimately relied upon in this research project were:

1. The 'Corruptions Perceptions Index' compiled by Transparency International;
2. The 'Index of Democracy' compiled by the Economic Intelligence Unit;
3. The 'Press Freedom Index' compiled by Reporters Without Borders
4. Per Capita Gross Domestic Product data compiled by the International Monetary Fund;
5. The 'Index of Economic Freedom' compiled by The Heritage Foundation with the Wall Street Journal;
6. The 'Human Development Indicators' compiled by the United Nations Development Programme; and
7. The 'Global Peace Index' compiled by the Institute for Economics and Peace.

<u>'Corruption Perceptions Index' compiled by Transparency International</u>

Founded in 1993 by Peter Eigan (a former regional director of the World Bank), Transparency International is a global civil society organisation that monitors corporate and political corruption in international development. Since 1995, Transparency International has published an annual 'Corruption Perceptions Index', which scores countries on the basis of how corrupt the public sector of that country is perceived to be (Transparency International: 2010a).

The 'Corruption Perceptions Index' is a composite index, drawing on surveys and datasets compiled by various reputable and independent institutions including the World Bank, the Economist Intelligence Unit, Freedom House and the World Economic Forum. Transparency International has been a participant in the United Nations Global Compact since 2003 (United Nations Global Contract: undated).

This study relies on Transparency International's 'Corruption Perceptions Indexes' from 2006 and 2010 to provide the datasets for corruption values in the respective years (Transparency International 2006; Transparency International 2010b). While the indexes measure 'corruption perceptions', rather than incidences of corruption, it is proposed that corruption perceptions are an appropriate proxy for corruption levels in countries for the reasons proffered by Transparency International in the 'frequently asked questions' section of their website:

> Corruption generally comprises illegal activities, which mainly come to light only through scandals, investigations or prosecutions. It is thus difficult to assess absolute levels of corruption in countries or territories on the basis of hard empirical data. Possible attempts to do so such as by comparing bribes reported, the number of prosecutions brought or court cases directly linked to corruption cannot be taken as definitive indicators of corruption levels. Rather they show how effective prosecutors, the courts or the media are in investigating and exposing corruption. One reliable method of compiling comparable country data is to capture perceptions of those in a position to offer expert assessments of public sector corruption in a given country (Transparency International 2010a: 3).

Somewhat counter-intuitively, the 'Corruption Perceptions Index' is structured so that a high score denotes low levels of corruption, while a low score denotes high levels of corruption. This means that when corruption values are plotted on a histogram, countries falling to the left hand side of the graph will have the lowest score, indicating that they have the highest levels of perceived corruption. Countries falling to the right hand side of the histogram have received higher scores, indicating that they have lower levels of perceived corruption.

'Index of Democracy' compiled by the Economist Intelligence Unit

The Economist Intelligence Unit – an independent organisation within the Economist Group – is a research and advisory company established in 1946. In 2007, the Economist Intelligence Unit released its first 'Index of Democracy', which measured the state of democracy in 167 countries in 2006 on the basis of 60 indicators divided into five categories; electoral process and pluralism, functioning of government, political participation and political culture (2007: 2). Updated indexes were published in 2008, and again in 2010.

In this project, the Economist Intelligence Unit's 'Indexes of Democracy' for 2007 (reporting 2006 data) and 2010 supplied the datasets for analysis in relation to the 'democracy' variable (Economist Intelligence Unit 2007; Economist Intelligence Unit 2010). The Economist Intelligence Unit's 'Indexes of Democracy' assign scores between 0 and 10 to indicate the state of democracy in a given country. Lower scores denote lower levels of democracy, while higher scores indicate the presence of strong democratic institutions and practices in the country in question.

‘Press Freedom Index’ compiled by Reporters Without Borders

Reporters Without Borders is a not-for-profit international organisation which advocates for freedom of the press. Based in France and established in 1985, Reporters Without Borders first published its ‘Press Freedom Index’ in 2002, and has issued updates every year since.

The ‘Press Freedom Index’ is compiled through the administration of a questionnaire which takes account of approximately 40 criteria (this figure varies from year to year) that assess the state of press freedom in each country. The questionnaire is circulated among partner organisations and correspondents around the world, as well as journalists, researchers, jurists and human rights activists (Reporters Without Borders 2010a).

In this project, Reporters Without Borders’ ‘Press Freedom Indexes’ for 2006 and 2010 supplied the datasets for analysis in relation to the ‘press freedom’ variable (Reporters Without Borders 2006; Reporters Without Borders 2010b). Somewhat counter-intuitively, higher levels of press freedom are indicated by lower scores, while higher scores denote lower levels of press freedom.

Per Capita Gross Domestic Product data compiled by the International Monetary Fund

The International Monetary Fund (IMF) is an institution within the United Nations system. The IMF describes itself as ‘an organization of 187 countries, working to foster global monetary cooperation, secure financial stability, facilitate international trade, promote high employment and sustainable economic growth, and reduce poverty around the world’ (2010a: 1). Founded at the Bretton-Woods conference towards the end of the Second World War, the IMF was established ‘to build a framework for economic cooperation that would avoid a repetition of the disastrous economic policies that had contributed to the Great Depression of the 1930s and the global conflict that followed’ (2010b: 5).

The IMF’s online ‘World Economic Outlook Database’ provides access to IMF data relating to the per capita GDPs of 180 countries throughout the world from 1988 to the present. It is also possible to access per capita GDP projection estimates prepared by IMF staff up until 2016. For the purposes of comparison, the per capita GDP figures relied upon in this study were the IMF’s Gross Domestic Product Per Capita figures at current prices, measured in US dollars and expressed in units (International Monetary Fund 2011).

‘Index of Economic Freedom’ compiled by The Heritage Foundation with the Wall Street Journal

The Heritage Foundation is an influential, conservative Washington-based research and educational institution (‘think-tank’), which was established in 1973. In 1995, The Heritage Foundation, together with the Wall Street Journal, published their first ‘Index of Economic Freedom’.

The index defines economic freedom as ‘the right of every human to control his or her own labor and property’ (Index of Economic Freedom 2011: 1). The index measures economic freedom by reference to ten different components: business freedom; trade freedom; fiscal freedom; government spending; monetary freedom; investment freedom; financial freedom; property rights; freedom from corruption; and labour freedom (Index of Economic Freedom 2011: 3). The index allocates countries a score between 0 and 100, with ten points possible in each component. Higher scores indicate higher levels of economic freedom, while lower scores denote lower levels of economic freedom. In this study, data relating to the ‘economic freedom’ variable was taken from the Indexes of Economic freedom for 2006 and 2010 respectively (The Heritage Foundation 2006; The Heritage Foundation 2010). The analysis of data generated by this index in addition to per capita GDP data is in recognition of the fact that poverty is multidimensional, and cannot be measured simply by reference to national income figures.

<u>‘Human Development Indicators’ compiled by the United Nations Development Programme</u>

The United Nations Development Programme is the United Nations’ global development network (2011: 1). In 1990, the United Nations Development Programme published its first ‘Human Development Report’, which is updated annually. A component of these ‘United Nations Human Development Reports’ each year is the ‘Human Development Index’, a composite statistic which is used to score countries on the basis of their level of human development. Included in the composite score awarded to each country are comparative measures of life expectancy, literacy, education and standards of living. Higher scores denote higher levels of human development, while lower scores indicate lower levels of human development.

Although the ‘Human Development Reports’ are updated annually, Human Development Indexes are not compiled every year. The Human Development Index included in the 2007/2008 ‘Human Development Report’ relied on data from 2005 (United Nations Development Programme 2008a). An updated index was published in 2008 independent of the publication of a ‘Human Development Report’, which reported on data up until 2006 and included newly released ‘purchasing power parities’ (United Nations Development Programme 2008b). The 2009 ‘Human Development Report’ relied on data up until 2007, while the 2010 ‘Human Development Report’ utilised 2010 data. The 2010 Human Development Index was the first to incorporate the ‘inequality adjusted human development index’ into the indices (United Nations Development Programme 2010).

In this study, the data from the 2008 Human Development Index was relied upon to provide data for 2006, while the 2010 Human Development Index relied upon to provide 2010 data (United Nations Development Programme 2008b; United Nations Development Programme 2010). Data relating to the ‘human development’ variable was analysed in conjunction with economic freedom data in exploration of the effect that national levels of socio-economic and human development have on the effort to eliminate lead additives from vehicular fuel.

'Global Peace Index' compiled by the Institute for Economics and Peace

The Institute for Economics and Peace is an independent, not-for-profit research institute. It was founded in 2007, and has offices in Sydney and New York. Together with the Economist Intelligence Unit and an international group of academics and peace experts, the Institute for Economics and Peace published its first 'Global Peace Index' in 2007 (Institute for Economics and Peace 2009a; Institute for Economics and Peace 2009b). The 'Global Peace Index' is updated on an annual basis.

A country's positioning in the 'Global Peace Index' is measured against 23 indicators: level of organized conflict; armed services personnel; weapons imports; military expenditure; number of conflicts fought; jailed population; deaths from conflict (internal); potential for terrorist acts; level of violent crime; political instability; military capability/sophistication; disrespect for human rights; number of homicides; UN Peacekeeping funding; number of heavy weapons; number of displaced people; neighbouring country relations; weapons exports; deaths from conflict (external); violent demonstrations; access to weapons; perceived criminality in society; and security officers & police.

Somewhat counter-intuitively, lower scores indicate higher levels of peacefulness, while higher scores denote lower levels of peacefulness. In this project, the Global Peace Indices of 2008 and 2010 were used to provide data in relation to the 'peacefulness' variable (Vision of Humanity 2008; Vision of Humanity 2010).

Limitations of the datasets

Although each of the indexes relied on in this study were published on multiple occasions between 2006 and 2010, the source surveys relied upon and the methodologies employed by the organisations in compiling these reports varied from year to year. This variation in data sources and methodologies between the annual indexes renders the datasets generated by these indexes inappropriate for the purposes of comparison over time. The absence of comparable time series data prevents cumulative point-in-time analysis, which in turn precludes the development of a definitive test of causality. Nonetheless, analysis of the data contained in the indexes can be used to establish the existence or absence of relationships between the identified potential determinants and the leaded/unleaded status of countries.

Although limitations in the datasets prevent this study from making definitive findings of causality, where the results reveal an absence of a relationship between the particular determinant and a country's status in relation to the continued use or successful elimination of leaded petrol, it can be stated with confidence that the factor is not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel. This is because even if the determinant was only partially causative of a failure to eliminate lead additives from vehicular fuel, a relationship of some description between the determinant and the lead status of countries would emerge in the data; although correlation does not establish causality, correlation is a necessary precondition for causation, so that an absence of correlation can be used to establish an absence of a causal relationship.

Where the data provides strong evidence of direct linkages between a particular determinant and a country's status in relation to the use or elimination of leaded petrol, it is possible to conclude that failures to address these factors in countries reliant on leaded fuel *may* be inhibiting the global effort to eliminate lead additives from vehicular fuel, whether or not a directly causative relationship exists between the variable and a country's leaded/unleaded status.

Phase Four: Data Analysis

The large number of datasets under consideration in this study meant that many of the datasets generated by the indexes did not naturally conform to a normal distribution. In order to accommodate these non-normal datasets, the quantitative data was analysed through a process of non-parametric comparative analysis. In further recognition of the high number of non-normal datasets included in the study, reference points for comparison were set at the median values of the datasets, rather than the mean values. For the purposes of consistency, non-parametric methodologies were used to analyse each of the datasets whether or not they naturally conformed to a normal distribution.

The generation of a histogram on the basis of the datasets facilitated visual comparative analysis and was used to identify potential relationships between the elimination of leaded additives to vehicular fuel and the potential determinants under consideration (corruption, democracy, press freedom, per capita GDP, economic freedom, human development and peacefulness). These observed relationships (e.g. that in 2006 countries that continued to use lead petrol exhibited lower levels of democracy than countries which had eliminated it) were posited as tentative hypotheses and subjected to more rigorous statistical tests to determine whether the observed relationships had emerged by chance, and whether the observed differences in the datasets were of any practical effect.

A numerical comparison of the median values of the two datasets (leaded and unleaded), visually represented through boxplots, was used to ascertain, prima facie, whether a difference existed between the leaded and unleaded countries with respect to the isolated determinant (corruption, democracy, press freedom , per capita gross domestic product, economic freedom, human development and peacefulness). Differences in median values of the datasets were taken as suggestive of a potential difference in the datasets for leaded and unleaded countries in relation to the determinant under consideration, and where differences in median values were observed, further statistical analysis was deemed warranted.

Where visual analysis of the frequency histogram and box-plots generated by the data suggested that elimination or continued use of leaded petrol was linked to the isolated variable in some manner, a determination of statistical significance was required. The test of statistical significance was used to determine whether the relationship between lead status and the isolated determinant (evident in the frequency histograms and box plots of the datasets) had emerged by chance or was indicative of a direct relationship between the two variables.

To this end, a Mann-Whitney test of statistical significance was conducted on the datasets. The null hypothesis in this test was that the leaded and unleaded datasets were statistically equal, with the alternate hypothesis that the two datasets were not statistically equal (that is, that the datasets were statistically different). Assigning a conventional α risk of 0.05, it was possible to state with a 95% confidence interval whether or not the differences between the datasets observed in the histograms and box-plots were statistically significant.

Where the Mann-Whitney test revealed that a statistically significant difference existed between the leaded and unleaded datasets, this was taken to evidence a strong likelihood that a relationship existed between the isolated determinant (corruption, democracy, press freedom, per capita gross domestic product, economic freedom, human development, and peacefulness) and lead status (whether or not leaded additives were still in use).

While a finding that two datasets are statistically significantly different supports the conclusion that the observed relationships between the dependent and independent variables in the datasets have not emerged by chance, statistical significance fails to provide any description of the substantiveness of the difference between the datasets. In other words, it is not possible to determine, solely on the basis of a finding of statistically significant difference, the practical effect of the difference in the datasets.

Consequently, subsequent to a finding of a statistically significant difference between the two datasets, it was desirable to determine whether a substantial difference existed between the leaded and unleaded countries. In order to determine whether a substantive practical difference existed in the corruption, democracy, press freedom, per capita gross domestic product, economic freedom, human development, or peacefulness values of the leaded countries as compared to their unleaded counterparts, it was necessary to perform a cumulative distribution function on the probability distribution of the leaded dataset, up to and including the median value of the unleaded dataset associated with the same determinant.

To this end, a probability distribution diagnosis was performed on the leaded dataset in order to determine the best fit. With the α risk set at 0.05, criteria for acceptance of an identified probability distribution of a leaded dataset was set by the return of a p value greater than 0.05. Where more than one probability distribution was identified as providing a good fit for the dataset (i.e. returning a p value greater than 0.05), the probability distribution returning the highest p value was applied. Where the probability distribution diagnosis identified that a transformation of the dataset would provide the best fit (e.g. through a Box-Cox transformation or a Johnson transformation) and an already determined probability distribution also met the criteria for acceptance (returning a p value greater than 0.05), the pre-determined probability distribution was applied. In these instances, the benefits of utilising the best-fit probability distribution identified by the diagnosis were considered outweighed by the complexities of the process associated with transforming the dataset, given that the pre-determined probability distribution was also identified as supplying a good fit for the dataset.

Once the best-fit probability distribution was identified for the leaded dataset, a cumulative probability function of the distribution was performed up to and including the median of the unleaded dataset. If the cumulative probability distribution indicated that a country in the leaded dataset was found to be four times more likely (or more than four times more likely) to return a value less than or equal to the median value of the unleaded countries, the practical difference in the leaded and unleaded countries in relation to the independent variable was considered substantial. It is noted, however, that the fixing of the test of 'substantial difference' at 'four times more likely to occur' is not a statistical convention, rather a benchmark for substantiveness that was selected at the discretion of the author.

Phase Five: Narrative Analysis of Results

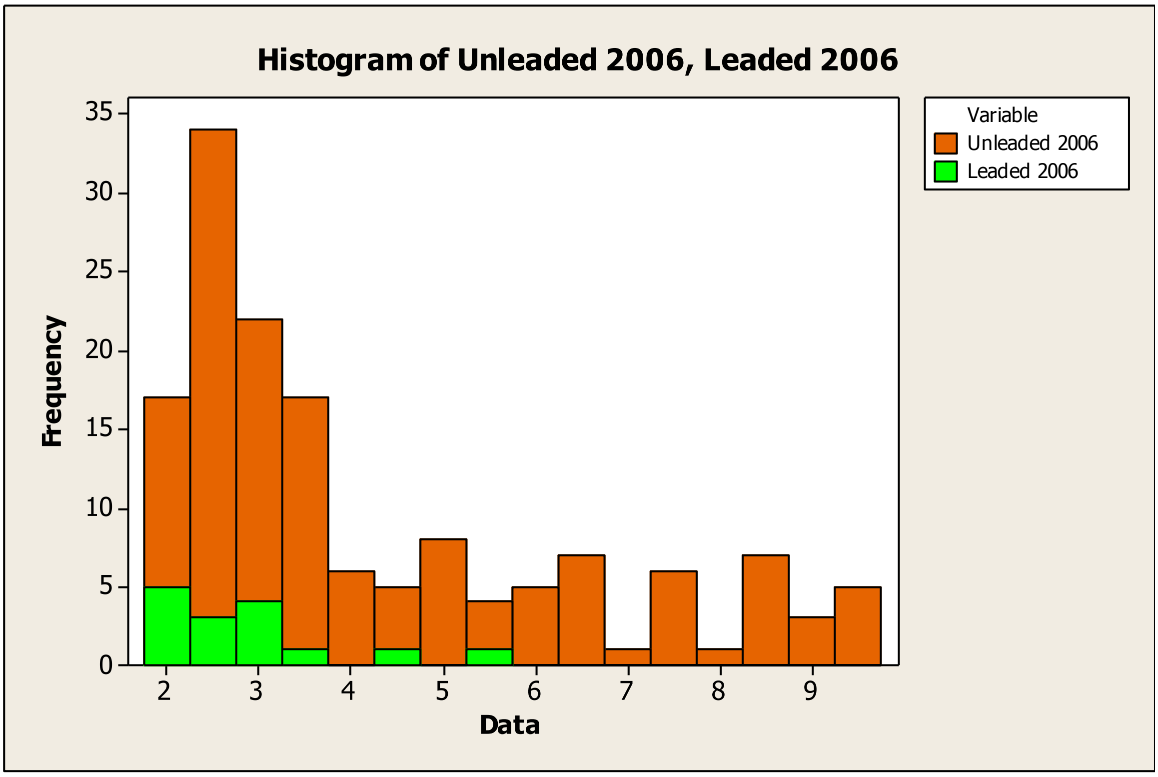
The findings of this study were then contextualised through reference to generalised theories of environmental reform. This narrative analysis of statistical findings facilitated the location of this research within the wider body of literature, and assisted in the development of directions for future research.

Results

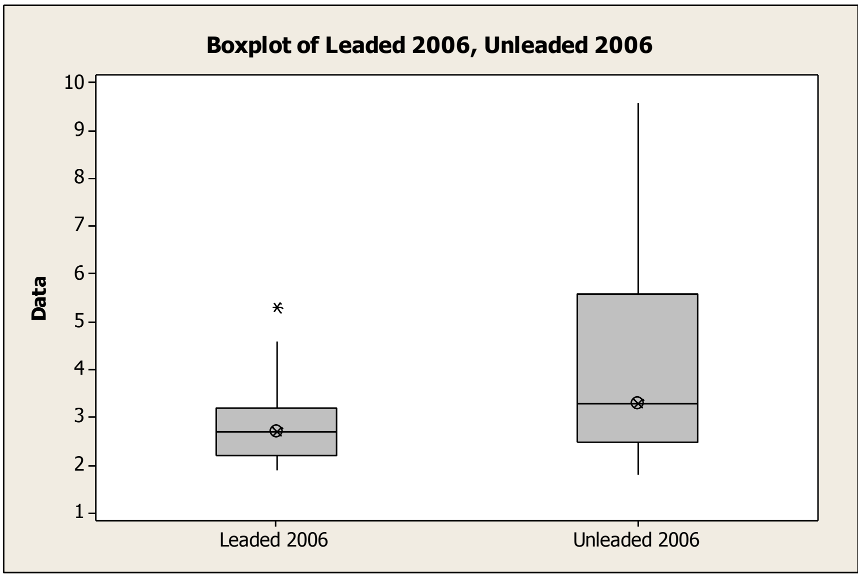
Corruption

Corruption and the Elimination of Leaded Petrol in 2006

In 2006, corruption data was available for the following countries which continued to use lead additives in their vehicular fuel: Algeria, Bosnia-Herzegovina, Egypt, Iraq, Jordan, Kazakhstan, Macedonia, Morocco, Myanmar, Serbia, Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for Afghanistan, North Korea, Palestine or Western Sahara. The Corruption Perceptions Index for 2006 assessed the corruption levels in 163 countries throughout the world (Transparency International 2006).



Visual comparative analysis of the frequency histogram generated by the data contained in the Corruption Perceptions Index 2006 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher corruption values (denoting lower levels of corruption) than countries which had not eliminated lead from their vehicular fuel. While a significant number of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of low levels of corruption), all of the countries which had not eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of high levels of corruption). It is noted that Jordan recorded a corruption value of 5.3 and that Tunisia was scored at 4.6, while the remainder of the leaded dataset was clumped to the leftmost side of the histogram.



Median of Leaded 2006

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Median of Leaded 2006 = 2.7
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Median of Unleaded 2006

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Median of Unleaded 2006 = 3.3
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A box plot of the median values of each of the datasets indicated that the median corruption value for countries that continued to use leaded petrol in 2006 was 2.7, while the median corruption value for countries that had eliminated leaded petrol in 2006 was 3.3. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2006, Unleaded 2006

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                 N  Median
Leaded 2006     15   2.700
Unleaded 2006  148   3.300


Point estimate for ETA1-ETA2 is -0.600
95.0 Percent CI for ETA1-ETA2 is (-1.500,-0.100)
W = 835.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0235
The test is significant at 0.0234 (adjusted for ties)
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A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0234, which was below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that a relationship existed between corruption values and the elimination or non-elimination of lead additives from vehicular fuel. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower corruption values (denoting higher levels of corruption) and a failure to eliminate lead from vehicular fuel in 2006 (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2006

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
15	0	2.90667	0.955784	2.7	1.9	5.3	1.44622	2.03267

Box-Cox transformation: Lambda = -1

Johnson transformation function:
-0.329955 + 1.71290 * Ln(X - 1.38006)

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.791	0.031	
Box-Cox Transformation	0.251	0.690	
Lognormal	0.378	0.361	
3-Parameter Lognormal	0.314	*	0.117
Exponential	3.659	<0.003	
2-Parameter Exponential	0.482	>0.250	0.000
Weibull	0.798	0.033	
3-Parameter Weibull	0.274	>0.500	0.005
Smallest Extreme Value	1.379	<0.010	
Largest Extreme Value	0.349	>0.250	
Gamma	0.495	0.228	
3-Parameter Gamma	0.285	*	0.066
Logistic	0.534	0.122	
Loglogistic	0.310	>0.250	
3-Parameter Loglogistic	0.328	*	0.167
Johnson Transformation	0.254	0.681	

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	2.90667		0.95578	
Box-Cox Transformation*	0.37332		0.10103	
Lognormal*	1.02349		0.29596	
3-Parameter Lognormal	-0.03344		0.75809	1.64480
Exponential			2.90667	
2-Parameter Exponential			1.07857	1.82810
Weibull		3.18960	3.23903	
3-Parameter Weibull		1.27727	1.23772	1.76231
Smallest Extreme Value	3.41907		1.12118	
Largest Extreme Value	2.51036		0.62944	
Gamma		11.65478	0.24940	
3-Parameter Gamma		2.11932	0.60536	1.62367
Logistic	2.77371		0.48066	
Loglogistic	1.00196		0.16091	
3-Parameter Loglogistic	-0.08530		0.48448	1.71040
Johnson Transformation*	0.11213		1.01532	

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a Box-Cox transformation probability distribution provided the best fit, returning a p value of 0.690. This indicated that the best fit for the dataset would be the normal probability distribution generated by a Box-Cox transformation.

In addition, the probability distribution diagnosis identified that a Johnson transformation probability distribution also provided a good fit for the dataset, returning a p value of 0.681.

The probability distribution diagnosis also identified that a 3-parameter Weibull probability distribution with a shape parameter of 1.27727, a scale parameter of 1.23772 and a threshold parameter of 1.76231 provided a good fit for the data, returning a p value of >0.500. This result was substantially above the assigned α risk of 0.05.

While the probability distributions which would have been generated through the performance of a Box-Cox transformation or a Johnson transformation of the leaded dataset would have provided the most appropriate probability distributions for the data – and would therefore have returned the most accurate statistical data – the high p value associated with the identified 3-parameter Weibull distribution meant that this also met the criteria for acceptance (p value ≥0.05) and was also suitable.

The generation of a probability distribution through the application of a transformation (Box-Cox or Johnson) would have required complex statistical analysis. Given that a 3-parameter Weibull probability distribution was also identified as meeting the criteria for acceptance and providing a good fit for the data, the benefits of utilising a probability distribution generated by the performance of a Box-Cox or Johnson transformation in preference to the identified 3-parameter Weibull probability distribution were outweighed by the complexities of the process. Consequently, the identified 3-parameter Weibull probability distribution of the leaded dataset was used to test the substantiveness of the statistical difference present in the two datasets.

Cumulative Distribution Function

```
Weibull with shape = 1.27727 and scale = 1.23772 and threshold = 1.76231

  x  P( X <= x )
3.3     0.732706
```

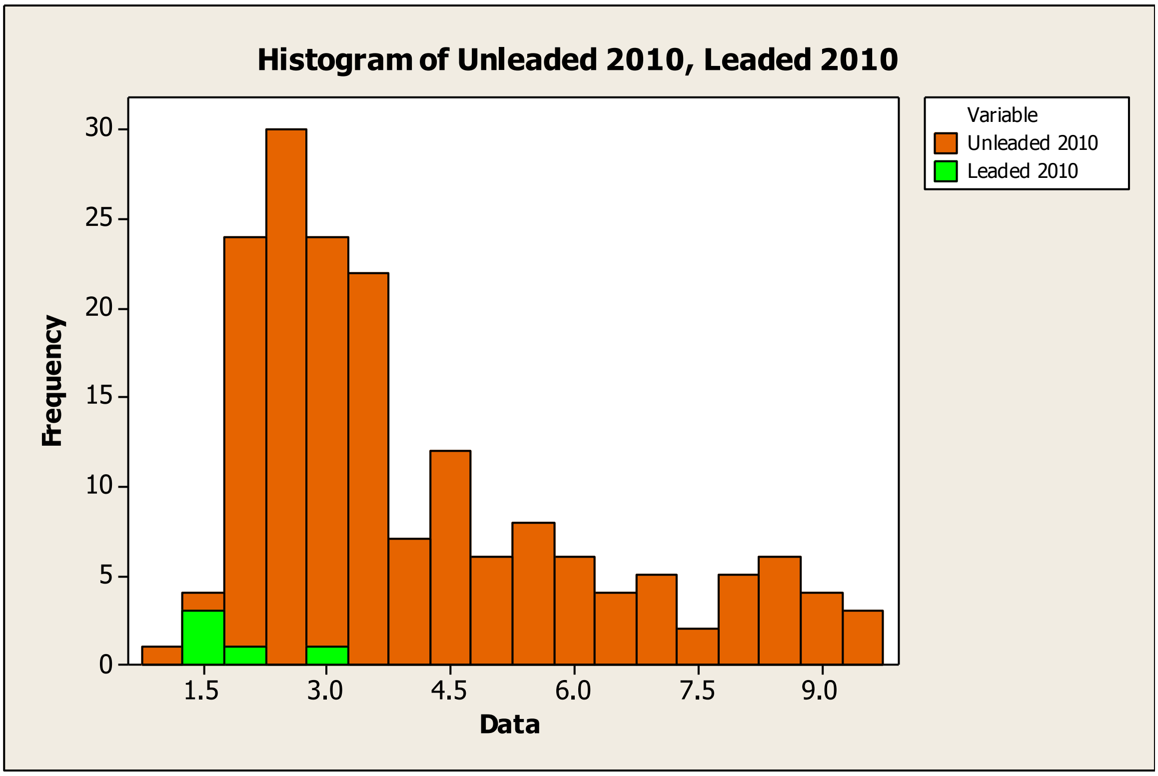
A cumulative distribution function of the identified 3-parameter Weibull probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 73.3% chance that a leaded country would have a corruption value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a corruption value greater than or equal to the average corruption level of unleaded countries was 26.7%. Recalling that higher corruption values were indicative of lower levels of corruption, this result indicates that leaded countries were noticeably more likely to exhibit higher levels of corruption than their unleaded counterparts.

In this study, the criteria for acceptance of the proposition that a substantial difference existed between the two datasets was fixed at a finding that it was at least four times more likely that a leaded country would have a corruption value lower than or equal to the median value of the unleaded countries. To establish this, the cumulative distribution function needed to return a minimum result of an 80% chance that a leaded country would have a corruption value lower than or equal to the mean of the unleaded countries. Consequently, in 2006, it could not be concluded with confidence that the practical difference in corruption levels between the leaded and unleaded countries was substantial.

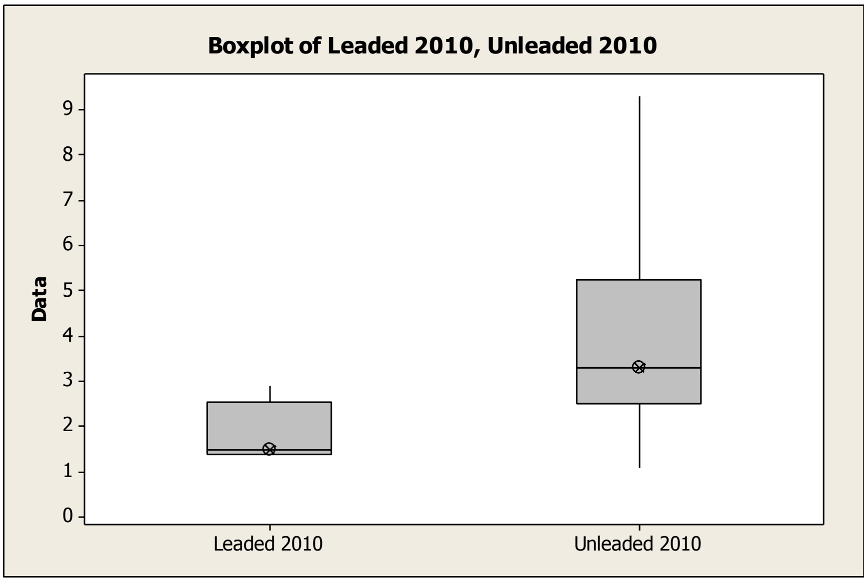
From the above results, it could be confidently asserted that in 2006 the likelihood that a country would continue to be reliant on leaded vehicular fuel was related to its level of corruption, and that leaded countries were more likely to be corrupt than unleaded countries, although the practical impact of this increased tendency towards higher levels of corruption could not be described as substantial. While it was not possible in the absence of comparable time series data to definitively state that the relationship between high corruption levels and continuing use of leaded vehicular fuel was causative in nature, it is clear that a close relationship between the two existed. These results provide some support for the conclusion that failures to address high levels of corruption in countries that continued to rely on leaded petrol may have been inhibiting the global effort to eliminate lead additives from vehicular fuel in 2006.

Corruption and the Elimination of Leaded Petrol in 2010

In 2010, corruption data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar and Yemen. Data was not available for North Korea. The Corruption Perceptions Index for 2010 assessed the corruption levels in 178 countries throughout the world (Transparency International 2010b).



Visual comparative analysis of the frequency histogram generated by the data contained in the Corruption Perceptions Index 2010 indicated that many more countries which had eliminated lead from their vehicular fuel displayed higher corruption values (denoting lower levels of corruption) than countries which had not eliminated lead from their vehicular fuel. While a significant number of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of low levels of corruption), all of the countries which had not eliminated lead from their vehicular fuel fell to the far left of the histogram (indicative of high levels of corruption). It is noted that Algeria is the only country among the leaded dataset which has committed to a phase out date (*UNEP PCFV* 2011: 7), and that with a score of 2.9, Algeria exhibited the lowest levels of corruption within the leaded dataset.



Median of Leaded 2010

```
Median of Leaded 2010 = 1.5
```

Median of Unleaded 2010

```
Median of Unleaded 2010 = 3.3
```

A box plot of the median values of each of the datasets indicated that the median corruption value for countries that continued to use leaded petrol in 2010 was 1.5, while the median corruption value for countries that had eliminated leaded petrol in 2010 was 3.3. The box plot therefore revealed a difference in the median values of the datasets – greater than the difference observed in the 2006 datasets – providing strong support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2010, Unleaded 2010

```
                 N  Median
Leaded 2010      5   1.500
Unleaded 2010  173   3.300


Point estimate for ETA1-ETA2 is -1.500
95.0 Percent CI for ETA1-ETA2 is (-3.400,-0.700)
W = 110.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0031
The test is significant at 0.0030 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0030, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that, as in 2006, a relationship existed between corruption values and the elimination or non-elimination of lead additives from vehicular fuel in 2010. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower corruption values (indicating higher levels of corruption) and a failure to eliminate lead from vehicular fuel in 2010 (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2010

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
5	0	1.88	0.661060	1.5	1.4	2.9	1.17972	-0.0148192

Box-Cox transformation: Lambda = -2.26427

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.505	0.103	
Box-Cox Transformation	0.452	0.148	
Lognormal	0.476	0.124	
3-Parameter Lognormal	0.482	*	0.066
Exponential	1.258	0.040	
2-Parameter Exponential	0.436	>0.250	0.001
Weibull	0.533	0.152	
3-Parameter Weibull	0.462	0.269	0.040
Smallest Extreme Value	0.572	0.113	
Largest Extreme Value	0.624	0.082	
Gamma	0.564	0.164	
3-Parameter Gamma	0.458	*	0.029
Logistic	0.539	0.099	
Loglogistic	0.517	0.122	
3-Parameter Loglogistic	0.418	*	0.039

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	1.88000		0.66106	
Box-Cox Transformation*	0.31807		0.17717	
Lognormal*	0.58632		0.32683	
3-Parameter Lognormal	-1.02509		1.04351	1.26927
Exponential			1.88000	
2-Parameter Exponential			0.59999	1.28000
Weibull		3.37520	2.09660	
3-Parameter Weibull		0.95359	0.57539	1.29130
Smallest Extreme Value	2.19536		0.62092	
Largest Extreme Value	1.61397		0.40362	
Gamma		11.28604	0.16658	
3-Parameter Gamma		0.71416	0.75047	1.34402
Logistic	1.79926		0.34994	
Loglogistic	0.55222		0.17749	
3-Parameter Loglogistic	-1.39919		0.79199	1.32509

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified a number of probability distributions that fit the dataset, returning p values greater than 0.05. The best fit identified by the probability diagnosis was a 3-parameter Weibull probability distribution with a shape parameter of 0.95359, a scale parameter of 0.57539 and a threshold parameter of 1.29130, returning a p value of 0.269.

Cumulative Distribution Function

```
Weibull with shape = 0.95359 and scale = 0.57539 and threshold = 1.2913

  x   P( X <= x )
3.3     0.962904
```

A cumulative distribution function of the identified 3-parameter Weibull probability distribution of the leaded dataset up to and including the median corruption value of the unleaded dataset revealed that there was a 96.3% chance that a leaded country would have a corruption value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a corruption value greater than or equal to the median corruption level of unleaded countries was 3.7%. Recalling that high corruption values denoted lower levels of corruption, this result indicated that it was very unlikely that a leaded country would exhibit the same amount or lower levels of corruption than the average unleaded country. The 96.3% chance that a leaded country would have a higher level of corruption than the median corruption level of the unleaded countries was significantly above the 80% minimum difference required for a classification of a practically substantial difference in the datasets.

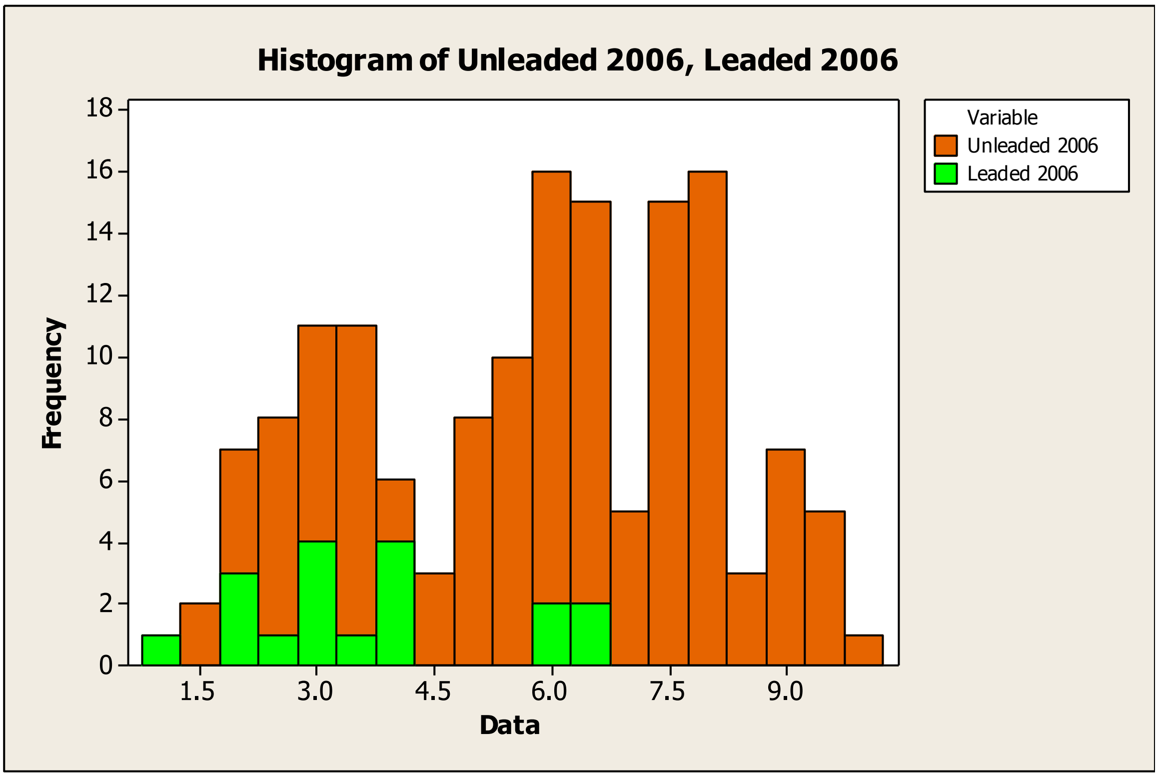
From these results, it can be concluded not only that a significant difference existed in the corruption values of leaded and unleaded countries in 2010, but also that the practical difference in corruption levels between the two was very substantial. While the divergence in corruption values in 2006 was clearly observable (although not within the scope of 'substantial' as defined by this study), this result indicates that the divergence in the corruption values of leaded countries as compared with unleaded countries was far greater in 2010 than it was in 2006. This indicates that the practical effect of the relationship between corruption values and a failure to eliminate lead from vehicular fuel was more pronounced in 2010 than it was in 2006.

From these findings, it can be confidently asserted that the likelihood that a country is leaded is related to its level of corruption, and that the relationship between corruption levels and the elimination of leaded petrol operated throughout the period 2006 to 2010. It is clear that leaded countries are substantially more likely to be corrupt than unleaded countries, and as time has progressed this trend has become even more pronounced. While in the absence of comparable time series data no definitive statement can be made as to whether the relationship between high levels of corruption and an increased tendency towards reliance on leaded fuel is causative in nature, the strength of the relationship provides considerable support for the proposition that failures to address high corruption levels in countries that continue to rely on leaded petrol may be inhibiting the global effort to eliminate lead additives from vehicular fuel. As the correlation between high corruption levels and reliance on leaded petrol became more pronounced in 2010 than it was in 2006, it can be asserted that the need to address the high levels of corruption present in leaded countries in order to further the global effort to eliminate lead additives from vehicular fuel was more compelling in 2010 than it was in 2006.

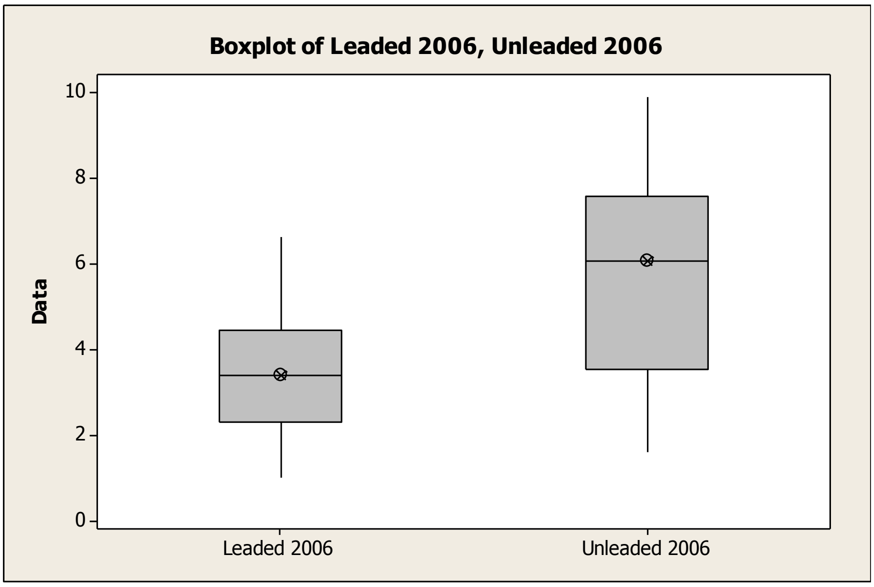
Democracy

Democracy and the Elimination of Leaded Petrol in 2006

In 2006, democracy data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Bosnia-Herzegovina, Egypt, Iraq, Jordan, Kazakhstan, North Korea, Macedonia, Morocco, Myanmar, Palestine, Serbia, Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for Western Sahara. The Democracy Index for 2006 assessed the democracy levels of 167 countries throughout the world (Economist Intelligence Unit 2007).



Visual comparative analysis of the frequency histogram generated by the data contained in the Democracy Index 2006 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher democracy values than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of high levels of democracy), while the majority of countries which had not eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of low levels of democracy). The four leaded countries returning democracy values above 5.5 were Macedonia, Serbia, Palestine and Bosnia-Herzegovina.



Median of Leaded 2006

```
Median of Leaded 2006 = 3.395
```

Median of Unleaded 2006

```
Median of Unleaded 2006 = 6.07
```

A box plot of the median values of each of the datasets indicated that the median democracy value for countries that continued to use leaded petrol in 2006 was 3.395, while the median democracy value for countries that had eliminated leaded petrol in 2006 was 6.07. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2006, Unleaded 2006

```
                 N  Median
Leaded 2006     18   3.395
Unleaded 2006  149   6.070


Point estimate for ETA1-ETA2 is -2.220
95.0 Percent CI for ETA1-ETA2 is (-3.370,-1.090)
W = 816.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0003
The test is significant at 0.0003 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0003, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that a relationship existed between democracy values and the elimination or non-elimination of leaded additives from vehicular fuel. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower democracy values and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2006

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
18	0	3.62722	1.64845	3.395	1.03	6.62	0.479675	-0.575954

Box-Cox transformation: Lambda = 0.5

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.520	0.161	
Box-Cox Transformation	0.352	0.427	
Lognormal	0.388	0.350	
3-Parameter Lognormal	0.361	*	0.397
Exponential	2.630	<0.003	
2-Parameter Exponential	1.610	<0.010	0.002
Weibull	0.413	>0.250	
3-Parameter Weibull	0.371	0.444	0.461
Smallest Extreme Value	0.920	0.017	
Largest Extreme Value	0.350	>0.250	
Gamma	0.357	>0.250	
3-Parameter Gamma	0.357	*	0.981
Logistic	0.492	0.171	
Loglogistic	0.365	>0.250	
3-Parameter Loglogistic	0.346	*	0.620

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	3.62722		1.64845	
Box-Cox Transformation*	1.85600		0.43956	
Lognormal*	1.18029		0.49998	
3-Parameter Lognormal	1.70723		0.28121	-2.10639
Exponential			3.62722	
2-Parameter Exponential			2.75000	0.87722
Weibull		2.44129	4.10166	
3-Parameter Weibull		1.88186	3.28932	0.70410
Smallest Extreme Value	4.45962		1.62148	
Largest Extreme Value	2.86492		1.34325	
Gamma		4.78226	0.75847	
3-Parameter Gamma		4.93374	0.74496	-0.04823
Logistic	3.51343		0.92954	
Loglogistic	1.20622		0.27739	
3-Parameter Loglogistic	1.54439		0.19368	-1.29453

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a 3-parameter Weibull probability distribution provided the best fit, returning the highest p value with a result of 0.444. The diagnosis identified that the best fit for the data was a 3-parameter Weibull probability distribution with a shape parameter of 1.88186, a scale of parameter of 3.28932 and a threshold parameter of 0.70410.

Cumulative Distribution Function

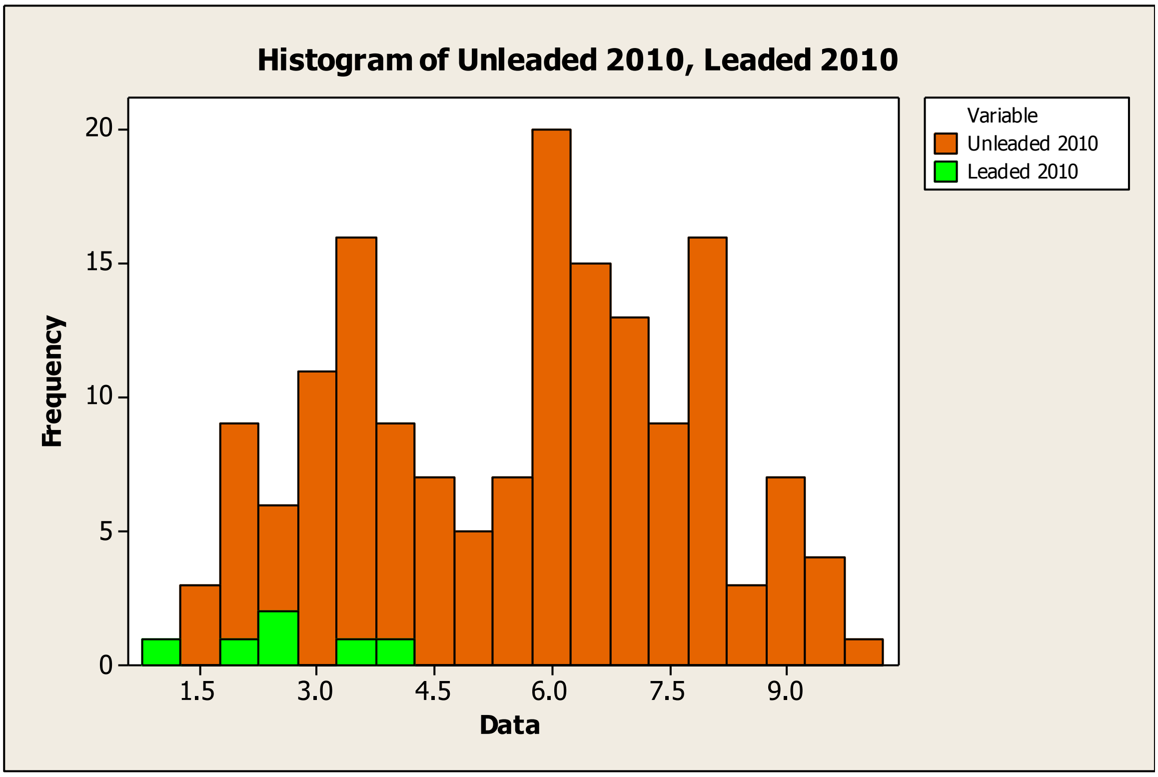
```
Weibull with shape = 1.88186 and scale = 3.28932 and threshold = 0.7041

   x  P( X <= x )
6.07     0.918868
```

A cumulative distribution function of the identified 3-parameter Weibull probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 91.9% chance that a leaded country would have a democracy value lower than or equal to the median democracy level of the unleaded countries. This meant that the likelihood of a leaded country having a democracy value greater than or equal to the average democracy level of unleaded countries was 8.1%. From this analysis, it can be concluded not only that a significant difference existed in the democracy values of leaded and unleaded countries in 2006, but also that the practical difference in democracy levels between the two was substantial.

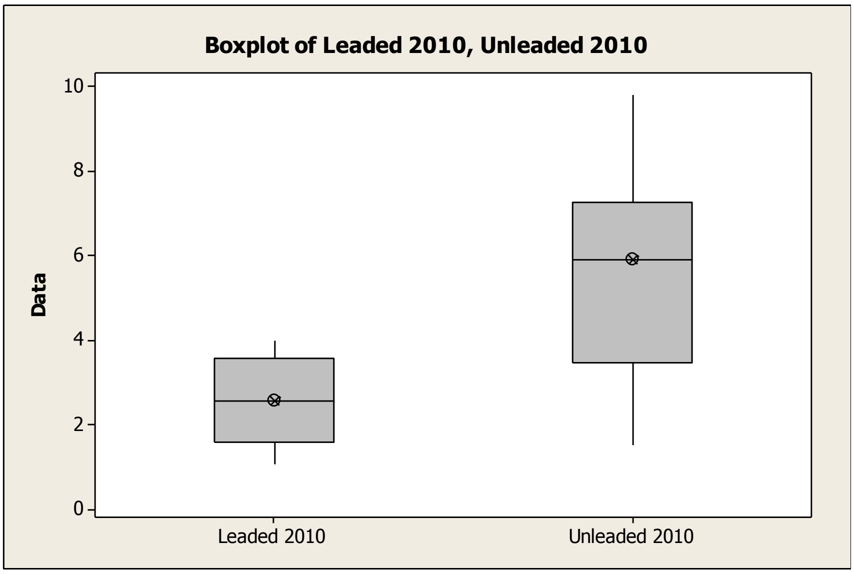
From these findings, it can be confidently asserted that in 2006 the likelihood that a country was leaded was related to its level of democracy, and that leaded countries were substantially less likely to be democratic than unleaded countries. While it is not possible in the absence of comparable time series data to definitively state that the relationship between low democracy levels and continuing use of leaded vehicular fuel was causative in nature, it is clear that a close relationship between the two existed. These findings provide strong support for the proposition that failures to address the low levels of democracy present in countries that continued to rely on leaded petrol may have been inhibiting the global effort to eliminate lead additives from vehicular fuel in 2006.

Democracy and the Elimination of Leaded Petrol in 2010

In 2010, democracy values were available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen. The Democracy Index for 2010 assessed the democracy levels of 167 countries throughout the world (Economist Intelligence Unit 2010).



Visual comparative analysis of the frequency histogram generated by the data contained in the Democracy Index 2010 indicated that many more countries which had eliminated lead from their vehicular fuel displayed higher democracy values than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of high levels of democracy), while all of the countries which had not eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of low levels of democracy). This visual comparative analysis of the datasets provided prima facie support for the proposition that the relationship between democracy values and the continued use/elimination of lead additives was more prominent in 2010 than it was in 2006.



Median of Leaded 2010

```
Median of Leaded 2010 = 2.56
```

Median of Unleaded 2010

```
Median of Unleaded 2010 = 5.92
```

A box plot of the median values of each of the datasets indicated that the median democracy value for countries that continued to use leaded petrol in 2010 was 2.56, while the median democracy value for countries that had eliminated leaded petrol in 2010 was 5.92. The box plot therefore revealed a difference in the median values of the datasets – greater than the difference observed in the 2006 datasets – providing strong support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2010, Unleaded 2010

```
                 N  Median
Leaded 2010      6   2.560
Unleaded 2010  161   5.920


Point estimate for ETA1-ETA2 is -3.160
95.1 Percent CI for ETA1-ETA2 is (-4.730,-1.230)
W = 145.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0021
The test is significant at 0.0021 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0021, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that, as in 2006, a relationship existed between democracy values and the elimination or non-elimination of lead additives from vehicular fuel in 2010. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower democracy values and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2010

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
6	0	2.56833	1.06535	2.56	1.08	4	-0.0519167	-0.766190

Box-Cox transformation: Lambda = 1

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.151	0.917	
Box-Cox Transformation	0.151	0.917	
Lognormal	0.231	0.663	
3-Parameter Lognormal	0.180	*	0.435
Exponential	1.049	0.079	
2-Parameter Exponential	0.787	0.063	0.037
Weibull	0.186	>0.250	
3-Parameter Weibull	0.199	>0.500	0.893
Smallest Extreme Value	0.211	>0.250	
Largest Extreme Value	0.213	>0.250	
Gamma	0.215	>0.250	
3-Parameter Gamma	0.798	*	1.000
Logistic	0.174	>0.250	
Loglogistic	0.229	>0.250	
3-Parameter Loglogistic	0.174	*	0.519

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	2.56833		1.06535	
Box-Cox Transformation*	2.56833		1.06535	
Lognormal*	0.85812		0.47523	
3-Parameter Lognormal	6.33481		0.00172	-561.29710
Exponential			2.56833	
2-Parameter Exponential			1.78599	0.78233
Weibull		2.95811	2.88672	
3-Parameter Weibull		2.47064	2.48741	0.36564
Smallest Extreme Value	3.05095		0.87522	
Largest Extreme Value	2.08218		0.89353	
Gamma		6.03491	0.42558	
3-Parameter Gamma		578.17703	0.04049	-21.29544
Logistic	2.57182		0.58508	
Loglogistic	0.89781		0.25294	
3-Parameter Loglogistic	6.34628		0.00103	-567.79541

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified a number of probability distributions that fit the dataset, returning p values greater than 0.05. The best fit identified by the probability diagnosis was a normal probability distribution with a location parameter of 2.56833 and a scale parameter of 1.06535, returning a p value of 0.917.

Cumulative Distribution Function

```
Normal with mean = 2.56833 and standard deviation = 1.06535

   x  P( X <= x )
5.92     0.999173
```

A cumulative distribution function of the identified normal probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 99.9% chance that a leaded country would have a democracy value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a democracy value greater than or equal to the average democracy level of unleaded countries was 0.1%.

From this result, it could be concluded not only that a significant difference existed in the democracy values of leaded and unleaded countries in 2010, but also that the practical difference in democracy levels between the two was very substantial. Furthermore, this result indicated that the divergence in the democracy values of leaded countries as compared with unleaded countries was even greater in 2010 than it was in 2006.

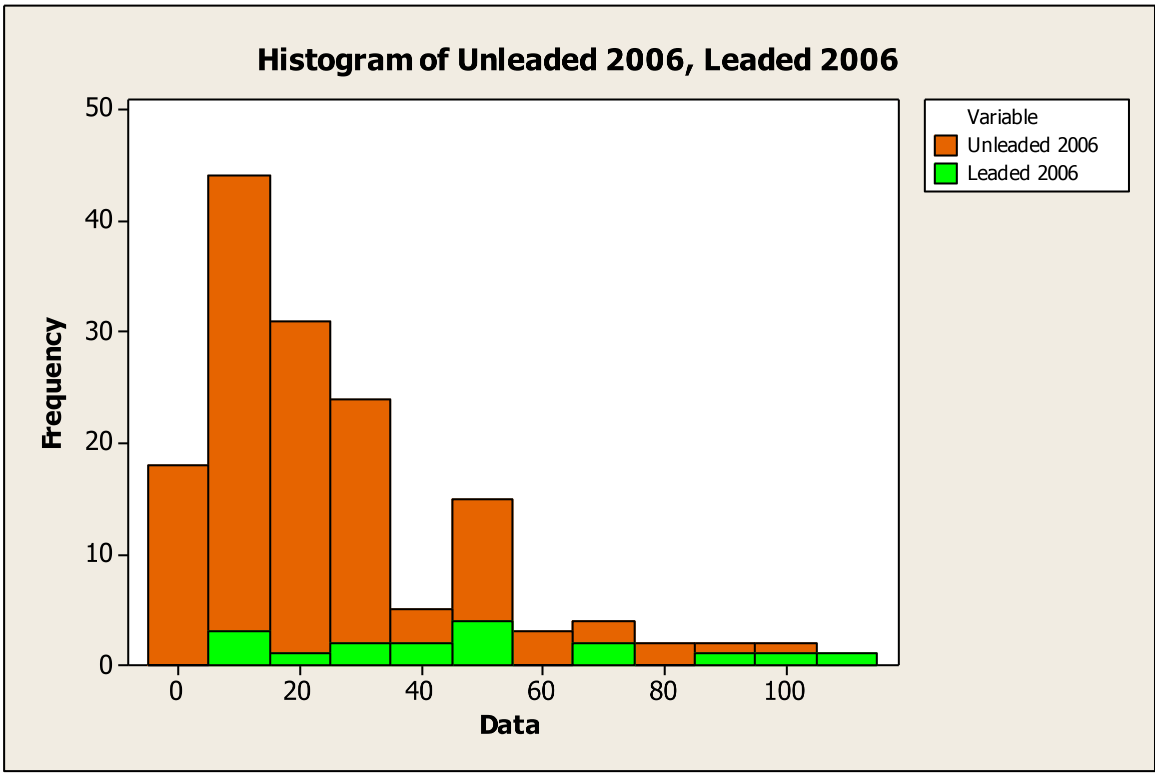
From these findings, it can be confidently asserted that the likelihood that a country is leaded is related to its level of democracy, and that the relationship between democracy levels and the elimination of leaded petrol operated throughout the period 2006 to 2010. It is clear that leaded countries are substantially less likely to be democratic than unleaded countries, and that as time has progressed this trend has become even more pronounced.

While in the absence of comparable time series data no definitive statement can be made as to whether the relationship between low levels of democracy and an increased tendency towards reliance on leaded vehicular fuel is causative in nature, the strength of the relationship provides considerable support for the proposition that failures to address low democracy levels in countries that continue to rely on leaded petrol may be inhibiting the global effort to eliminate lead additives from vehicular fuel. As the correlation between low democracy levels and reliance on leaded petrol became more pronounced in 2010 than it was in 2006, it can be asserted that the need to address the low levels of democracy present in leaded countries in order to further the global effort to eliminate lead additives from vehicular fuel was more compelling in 2010 than it was in 2006.

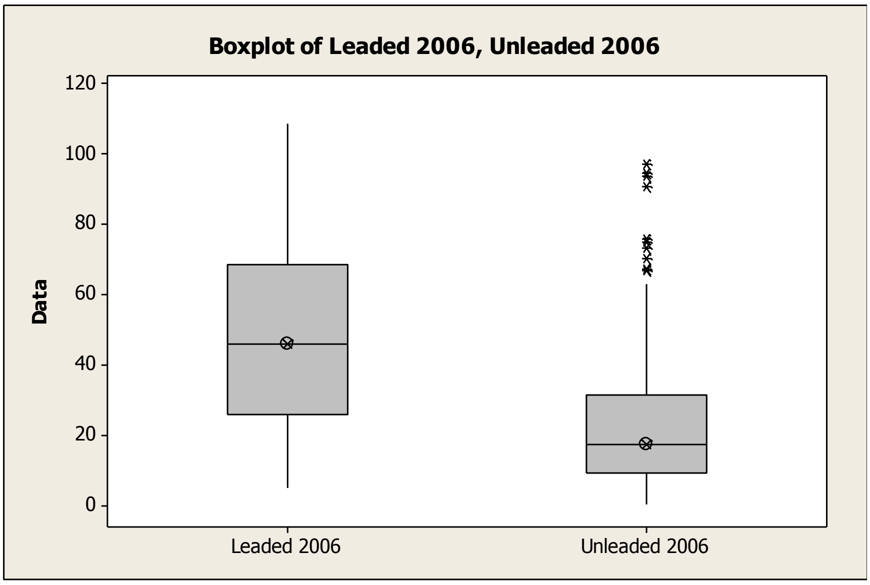
Press Freedom

Press Freedom and the Elimination of Leaded Petrol in 2006

In 2006, press freedom data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Bosnia-Herzegovina, Egypt, Iraq, Jordan, Kazakhstan, Macedonia, Morocco, Myanmar, North Korea, Palestine, Serbia (under the name 'Serbia and Montenegro'), Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for Western Sahara. The 'Press Freedom Index' for 2006 assessed press freedom levels in 168 countries throughout the world (Reporters Without Borders 2006).



Visual comparative analysis of the frequency histogram generated by the data contained in the Press Freedom Index 2006 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher levels of press freedom than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of high levels of press freedom), while the countries which had not eliminated lead from their vehicular fuel were more evenly spread across the histogram. A greater proportion of countries falling to the right of the histogram (indicative of low levels of press freedom) had not eliminated leaded additives from their vehicular fuel.



Median of Leaded 2006

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Median of Leaded 2006 = 46.25
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Median of Unleaded 2006

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Median of Unleaded 2006 = 17.5
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A box plot of the median values of each of the datasets indicated that the median press freedom value for countries that continued to use leaded petrol in 2006 was 46.25, while the median press freedom value for countries that had eliminated leaded petrol in 2006 was 17.5. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2006, Unleaded 2006

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                 N  Median
Leaded 2006     17   46.25
Unleaded 2006  150   17.50


Point estimate for ETA1-ETA2 is 23.50
95.0 Percent CI for ETA1-ETA2 is (10.17,36.50)
W = 2057.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0009
The test is significant at 0.0009 (adjusted for ties)
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A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0009, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets are statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that a relationship existed between press freedom values and the elimination or non-elimination of lead additives from vehicular fuel. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between higher press freedom values (denoting lower levels of press freedom) and a failure to eliminate lead from vehicular fuel in 2006 (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2006

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
17	0	48.9506	30.9297	46.25	5	109	0.548257	-0.460245

Box-Cox transformation: Lambda = 0.5

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.333	0.472	
Box-Cox Transformation	0.187	0.888	
Lognormal	0.521	0.159	
3-Parameter Lognormal	0.208	*	0.126
Exponential	0.990	0.111	
2-Parameter Exponential	1.047	0.048	0.206
Weibull	0.218	>0.250	
3-Parameter Weibull	0.243	>0.500	0.821
Smallest Extreme Value	0.704	0.058	
Largest Extreme Value	0.207	>0.250	
Gamma	0.268	>0.250	
3-Parameter Gamma	0.237	*	1.000
Logistic	0.303	>0.250	
Loglogistic	0.399	>0.250	
3-Parameter Loglogistic	0.207	*	0.286

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	48.95059		30.92966	
Box-Cox Transformation*	6.61579		2.34644	
Lognormal*	3.63375		0.83694	
3-Parameter Lognormal	4.39779		0.35303	-37.43989
Exponential			48.95059	
2-Parameter Exponential			46.69747	2.25309
Weibull		1.63846	54.60324	
3-Parameter Weibull		1.53092	52.04959	1.86045
Smallest Extreme Value	64.61288		30.91971	
Largest Extreme Value	34.75818		24.63543	
Gamma		2.09646	23.34912	
3-Parameter Gamma		19.47044	6.70033	-82.07973
Logistic	46.78618		17.42211	
Loglogistic	3.72494		0.44873	
3-Parameter Loglogistic	4.28995		0.23316	-29.06077

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a Box-Cox transformation probability distribution provided the best fit, returning a p value of 0.888. This indicated that the best fit for the dataset would be the normal probability distribution generated by a Box-Cox transformation.

The probability distribution diagnosis also identified that a 3-parameter Weibull probability distribution with a shape parameter of 1.53092 and a scale parameter of 52.04959 and a threshold parameter of 1.86045 provided a good fit for the data, returning a p value greater than 0.500. This result was substantially above the assigned α risk of 0.05.

While the normal distribution function generated through the application of Box-Cox transformation provided the most appropriate probability distribution for the leaded dataset, and would therefore have returned the most accurate statistical data, the high p value associated with the identified 3-parameter Weibull distribution meant that this also met the criteria for acceptance (p value ≥0.05) and was also suitable.

The generation of a normal dataset through the application of a Box-Cox transformation would have required complex statistical analysis. Given that a 3-parameter Weibull probability distribution was identified as meeting the criteria for acceptance and providing a good fit for the data, the benefits of utilising a probability distribution generated by the performance of a Box-Cox transformation were outweighed by the complexities of the process. Consequently, the identified 3-parameter Weibull probability distribution of the leaded dataset was used to test the substantiveness of the statistical difference that was present in the two datasets.

Cumulative Distribution Function

```
Weibull with shape = 1.53092 and scale = 52.0496 and threshold = 1.86045

   x  P( X <= x )
17.5     0.146744
```

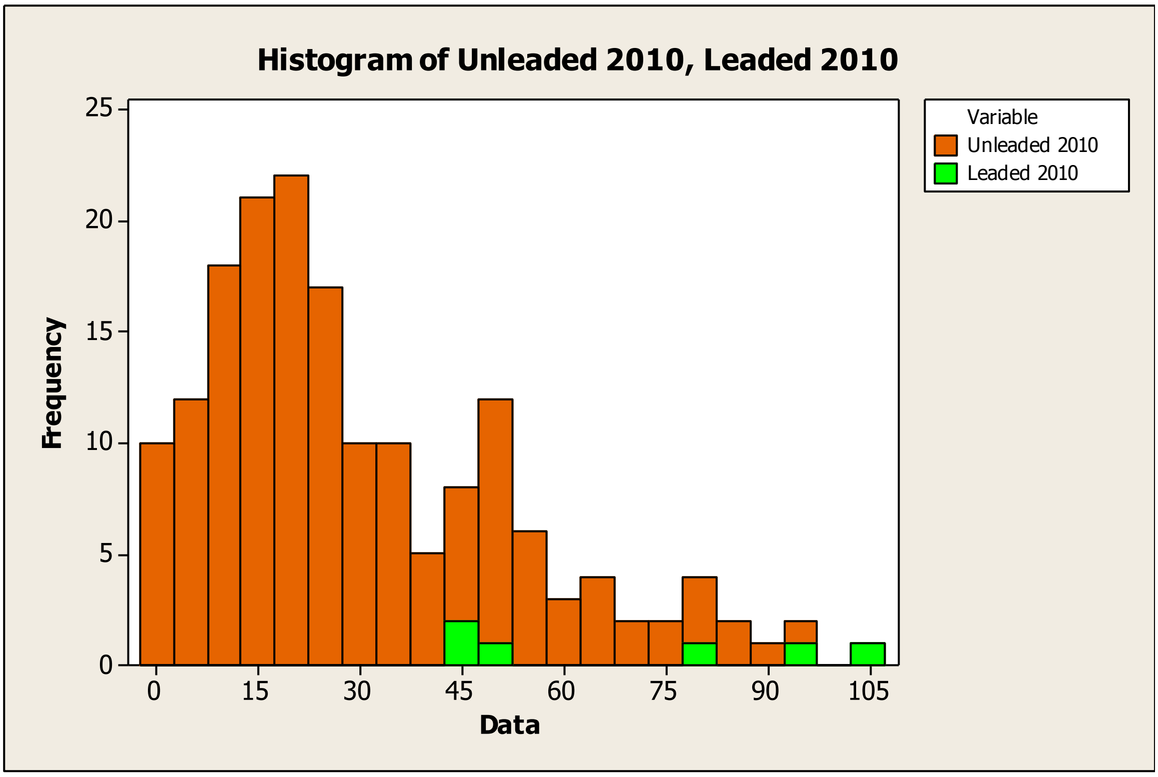
A cumulative distribution function of the identified 3-parameter Weibull probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 14.7% chance that a leaded country would have a press freedom value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a press freedom value greater than or equal to the average press freedom level of unleaded countries was 85.3%. From this analysis, it can be concluded not only that a significant difference existed in the press freedom values of leaded and unleaded countries in 2006, but also that the practical difference in press freedom levels between the two was substantial.

Recalling that lower press freedom values denoted higher levels of press freedom, it can be confidently asserted from these findings that the likelihood that a country was leaded was related to its level of press freedom, and that leaded countries were substantially less likely to have higher levels of press freedom than unleaded countries. While it is not possible in the absence of comparable time series data to definitively state that the relationship between low press freedom levels and continuing use of leaded vehicular fuel was causative in nature, it is clear that a close relationship between the two existed.

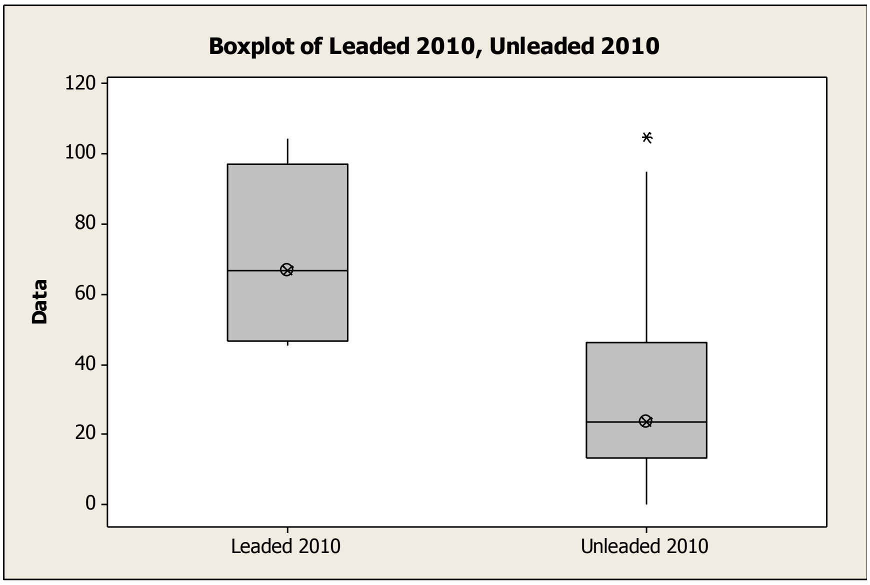
These findings provide strong support for the proposition that failures to address the low levels of press freedom present in countries that continued to rely on leaded petrol may have been inhibiting the global effort to eliminate lead additives from vehicular fuel in 2006.

Press Freedom and the Elimination of Leaded Petrol in 2010

In 2010, press freedom data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen. The 'Press Freedom Index' for 2010 assessed press freedom levels in 178 countries throughout the world (Reporters Without Borders 2010b).



Visual comparative analysis of the frequency histogram generated by the data contained in the Press Freedom Index 2010 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher levels of press freedom than countries which had not eliminated lead from vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of high levels of press freedom). Three of the countries which continued to use lead from their vehicular fuel recorded press freedom values towards the centre of the histogram, while the remaining three fell to the right side (indicative of low levels of press freedom). A greater proportion of countries falling to the far right of the histogram (indicative of low levels of press freedom) had not eliminated leaded additives from their vehicular fuel.



Median of Leaded 2010

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Median of Leaded 2010 = 66.9
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Median of Unleaded 2010

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Median of Unleaded 2010 = 23.5
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A box plot of the median values of each of the datasets indicated that the median press freedom value for countries that continued to use leaded petrol in 2010 was 66.9, while the median press freedom value for countries that had eliminated leaded petrol in 2010 was 23.5. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2010, Unleaded 2010

```
                  N  Median
Leaded 2010       6   66.90
Unleaded 2010   172   23.50


Point estimate for ETA1-ETA2 is 39.28
95.0 Percent CI for ETA1-ETA2 is (22.91,66.76)
W = 931.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0015
The test is significant at 0.0015 (adjusted for ties)
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A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0015, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible conclude with confidence that, as in 2006, a relationship existed between press freedom values and the elimination or non-elimination of leaded additives from vehicular fuel in 2010. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between higher press freedom values (denoting lower levels of press freedom) and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2010

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
6	0	70.9933	26.0587	66.9	45.58	104.75	0.270544	-2.47116

Box-Cox transformation: Lambda = -0.5

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.431	0.195	
Box-Cox Transformation	0.456	0.165	
Lognormal	0.447	0.175	
3-Parameter Lognormal	0.521	*	1.000
Exponential	1.313	0.037	
2-Parameter Exponential	0.494	0.221	0.001
Weibull	0.495	0.194	
3-Parameter Weibull	0.512	0.206	0.352
Smallest Extreme Value	0.462	0.227	
Largest Extreme Value	0.560	0.128	
Gamma	0.527	0.198	
3-Parameter Gamma	0.518	*	1.000
Logistic	0.474	0.176	
Loglogistic	0.492	0.155	
3-Parameter Loglogistic	0.481	*	0.362

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	70.99333		26.05872	
Box-Cox Transformation*	0.12392		0.02276	
Lognormal*	4.20500		0.37313	
3-Parameter Lognormal	4.37252		0.29016	-12.55404
Exponential			70.99333	
2-Parameter Exponential			30.49535	40.49744
Weibull		3.35537	79.46100	
3-Parameter Weibull		1.76387	45.12180	31.03466
Smallest Extreme Value	83.01938		21.58775	
Largest Extreme Value	59.45358		19.22051	
Gamma		8.84531	8.02610	
3-Parameter Gamma		9.91869	7.56775	-4.81252
Logistic	70.19203		15.05660	
Loglogistic	4.19984		0.21732	
3-Parameter Loglogistic	3.37110		0.46796	33.73771

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a smallest extreme value probability distribution provided the best fit, returning the highest p value with a result of 0.227. The diagnosis identified that the best fit for the data was a smallest extreme value probability distribution with the parameters of a location of 83.01938 and a scale of 21.58775.

Cumulative Distribution Function

```
Smallest Extreme Value with location = 83.0194 and scale = 21.5878

   x  P( X <= x )
23.5    0.0615035
```

A cumulative distribution function of the identified smallest extreme value probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 6.2% chance that a leaded country would have a press freedom value lower than or equal to the median press freedom value of the unleaded countries. This meant that the likelihood of a leaded country having a press freedom value greater than or equal to the median press freedom value of unleaded countries was 93.9%. Recalling that high press freedom values denoted lower levels of press freedom, this result indicated that it was very unlikely that a leaded country would exhibit the same amount or greater press freedom than the average unleaded country.

From this result, it can be concluded not only that a significant difference existed in the press freedom values of leaded and unleaded countries in 2010, but also that the practical difference in press freedom levels between the two was very substantial. Furthermore, this result indicates that the divergence in the press freedom values of leaded countries as compared with unleaded countries was even greater in 2010 than it was in 2006.

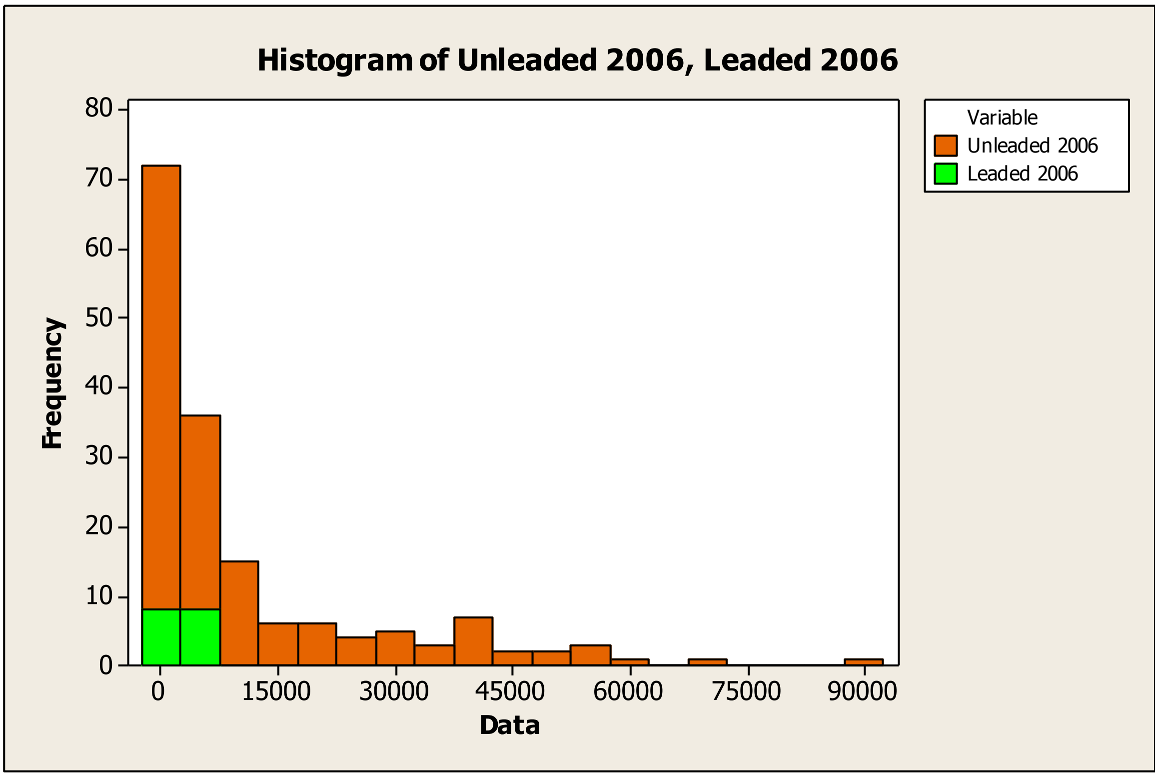
From these findings, it can be confidently asserted that the likelihood that a country is leaded is related to its level of press freedom, and that this relationship between press freedom levels and the elimination of leaded vehicular fuel operated throughout the period 2006 to 2010. It is clear that leaded countries are substantially less likely to exhibit press freedom than unleaded countries, and that as time has progressed this trend has become even more pronounced.

While in the absence of comparable time series data no definitive statement can be made as to whether the relationship between low levels of press freedom and an increased tendency towards reliance on leaded fuel is causative in nature, the strength of the relationship provides considerable support for the proposition that failures to address low press freedom levels in countries that continue to rely on leaded petrol may be inhibiting the global effort to eliminate lead additives from vehicular fuel. As the correlation between low press freedom levels and reliance on leaded petrol became more pronounced in 2010 than it was in 2006, it can be asserted that the need to address the low levels of press freedom present in leaded countries in order to further the global effort to eliminate lead additives from vehicular fuel was more compelling in 2010 than it was in 2006.

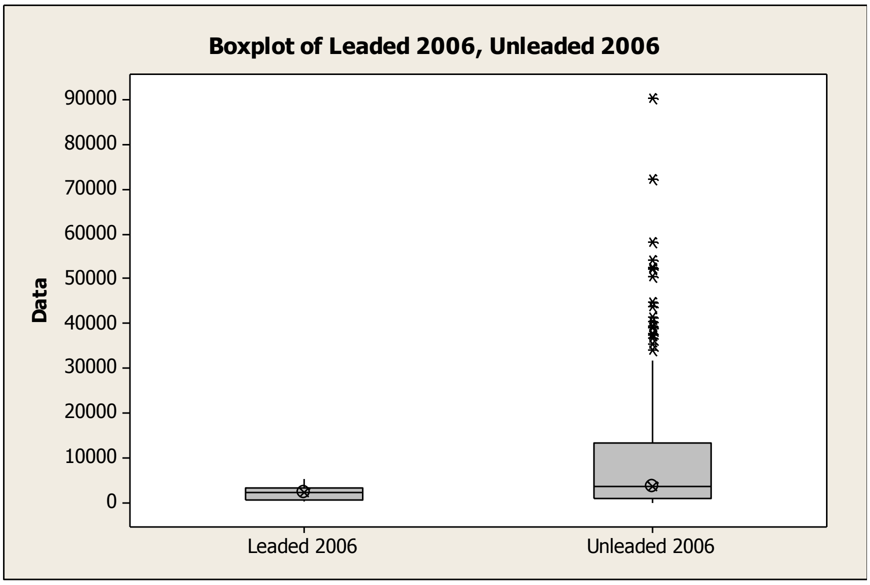
Per Capita Gross Domestic Product

Per Capita Gross Domestic Product (GDP) and the Elimination of Leaded Petrol in 2006

In 2006, per capita GDP data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Bosnia-Herzegovina, Egypt, Iraq, Jordan, Kazakhstan, Macedonia, Morocco, Myanmar, Serbia, Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for North Korea, Palestine or Western Sahara. In 2006, the IMF provided data about per capita GDP for 179 countries throughout the world (International Monetary Fund 2011).



Visual comparative analysis of the frequency histogram generated by the data contained in the per capita GDP Index 2006 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher per capita GDP values than countries which had not eliminated lead from their vehicular fuel. Both datasets tended heavily towards the left hand side of the histogram, indicating lower levels of per capita GDP. While the unleaded countries were spread (unevenly) along the histogram, all of the leaded countries fell to the far left hand side of the histogram, indicating very low per capita GDP values. The outlying unleaded countries, returning per capita GDPs of 90198.741 and 72074.458 respectively, were Luxemburg and Norway.



Median of Leaded 2006

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Median of Leaded 2006 = 2472.78
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Median of Unleaded 2006

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Median of Unleaded 2006 = 3753.55
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A box plot of the median values of each of the datasets indicated that the median per capita GDP value for countries that continued to use leaded petrol in 2006 was 2472.78, while the median per capita GDP value for countries that had eliminated leaded petrol in 2006 was 3753.55. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2006, Unleaded 2006

```
                 N  Median
Leaded 2006     16  2472.8
Unleaded 2006  164  3753.5

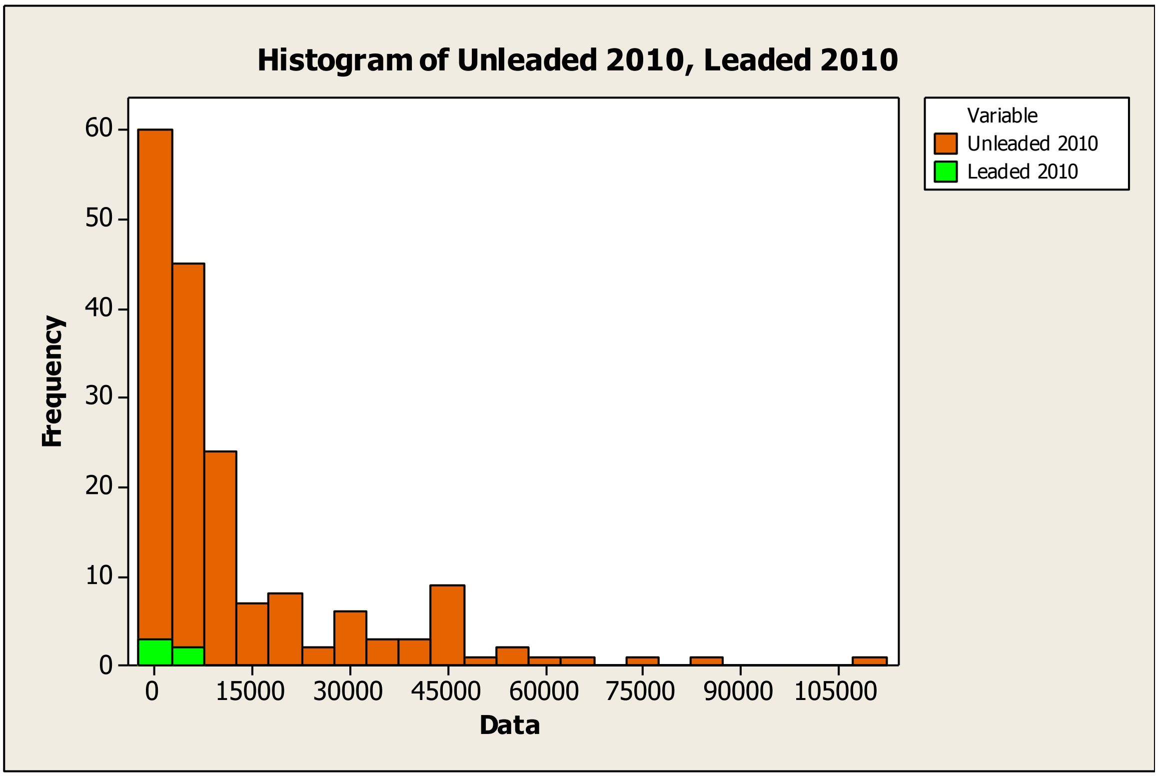

Point estimate for ETA1-ETA2 is -1534.9
95.0 Percent CI for ETA1-ETA2 is (-5109.0,40.4)
W = 1064.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0542
The test is significant at 0.0542 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0542, which was above the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was accepted, and the alternate hypothesis that a statistically significant difference existed between the two datasets was rejected.

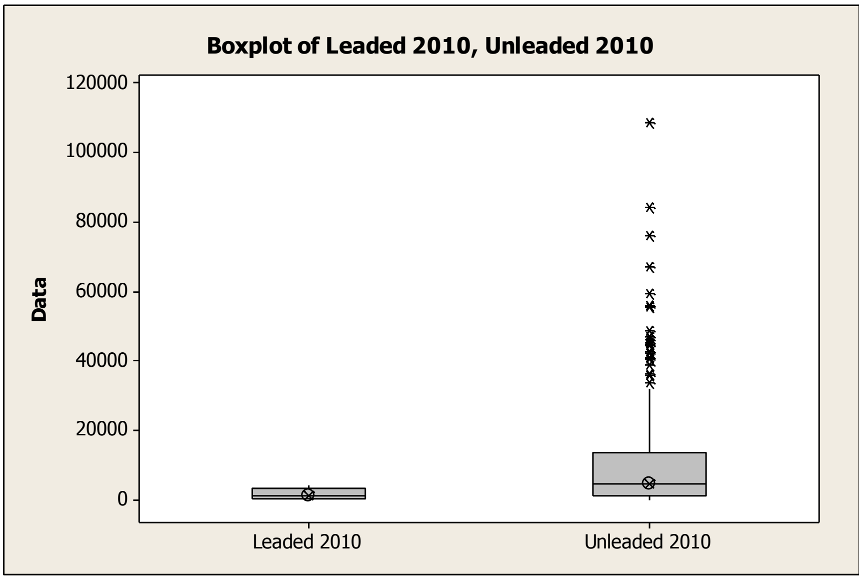
The finding that the datasets were statistically equal meant that it could be concluded with confidence that any relationship which may have been observed between per capita GDP and a failure to eliminate leaded petrol in 2006 (e.g. in the histograms or box plots generated by the data) emerged by chance. Were the relationship between per capita GDP values and a country's decision to continue to rely upon or to eliminate lead additives from petrol even partially causative in nature, it would have been possible to detect a relationship between the two factors (per capita GDP and lead status) that did not emerge by chance. The finding that no such correlation exists between the factors makes it possible to conclude with confidence that the slightly lower median levels of per capita GDP observable in leaded countries as compared with their unleaded counterparts (observed in the histogram and box plot generated by the data) was not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel in 2006.

Per Capita Gross Domestic Product (GDP) and the Elimination of Leaded Petrol in 2010

In 2010, per capita GDP values were available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar and Yemen. Data was not available for North Korea. In 2010, the IMF provided data about per capita GDP for 180 countries throughout the world (International Monetary Fund 2011).



Visual comparative analysis of the frequency histogram generated by the 2010 per capita GDP data indicated that many more countries which had eliminated lead from their vehicular fuel displayed higher per capita GDP values than countries which had not eliminated lead from their vehicular fuel. Although both datasets tended towards the left of the histogram (indicating low per capita GDPs), some countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of higher per capita GDPs), while all of the countries which had not eliminated lead from their vehicular fuel fell to the far left of the histogram (indicative of lower per capita GDPs).



Median of Leaded 2010

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Median of Leaded 2010 = 1281.81
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Median of Unleaded 2010

```
Median of Unleaded 2010 = 4740.85
```

A box plot of the median values of each of the datasets indicated that the median per capita GDP value for countries that continued to use leaded petrol in 2010 was 1281.81, while the median per capita GDP value for countries that had eliminated leaded petrol in 2010 was 4740.85. The box plot therefore revealed a difference in the median values of the datasets – greater than the difference observed in the 2006 datasets – providing support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2010, Unleaded 2010

```
                 N  Median
Leaded 2010      5  1281.8
Unleaded 2010  175  4740.9


Point estimate for ETA1-ETA2 is -3088.2
95.1 Percent CI for ETA1-ETA2 is (-12560.4,108.0)
W = 246.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0736
The test is significant at 0.0736 (adjusted for ties)
```

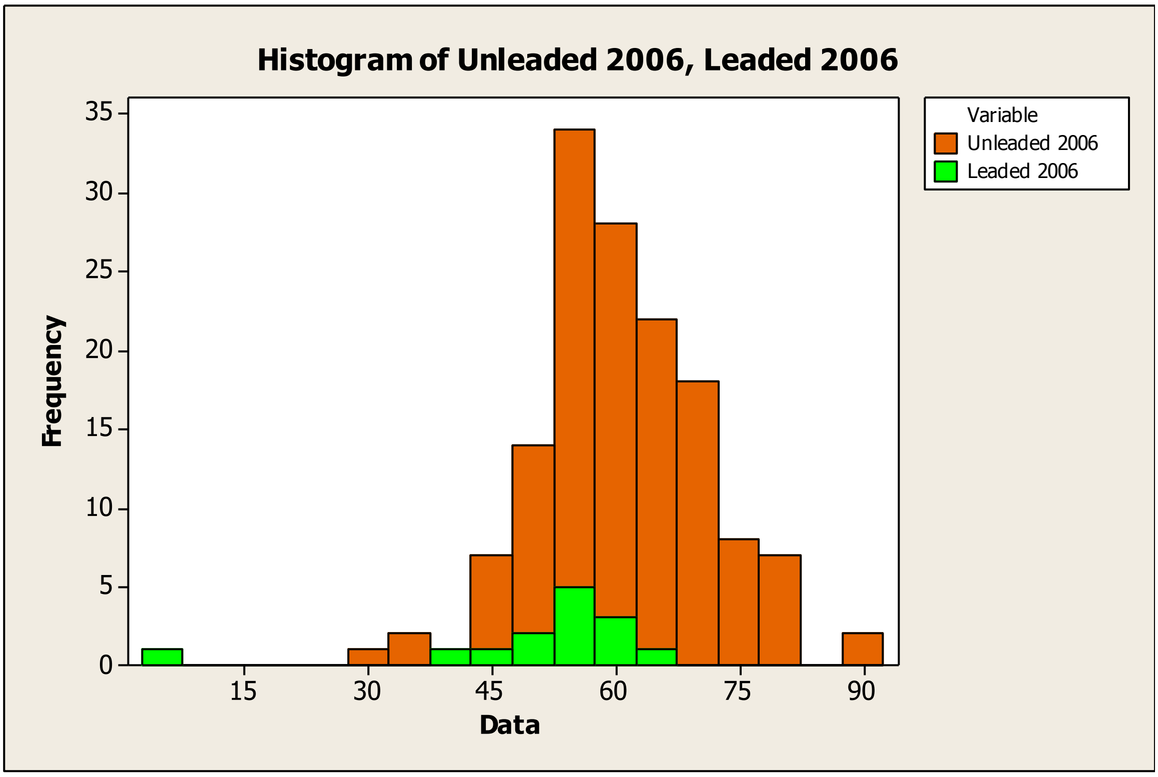
A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0736, which was above the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was accepted, and the alternate hypothesis that a statistically significant difference existed between the two datasets was rejected.

The finding that the datasets were statistically equal meant that it was possible to conclude with confidence that any relationship which may have been observed between per capita GDP values and a failure to eliminate leaded petrol in 2010 (e.g. in the histograms or box plots generated by the data) emerged by chance. The absence of a correlation between a country's per capita GDP levels and its status in relation to the elimination of leaded fuel denies the possibility of a causal relationship between the factors. Consequently, it is possible to conclude that, as in 2006, the lower levels of per capita GDP observable in leaded countries as compared with their unleaded counterparts (in the histogram and box plot generated by the data) was not acting as a barrier to the elimination of lead additives from vehicular fuel in 2010. It can be concluded with confidence that there is no causative relationship between per capita GDP levels and the elimination of lead additives from vehicular fuel, and that the per capita GDP values present in countries still reliant on leaded fuel today is not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel.

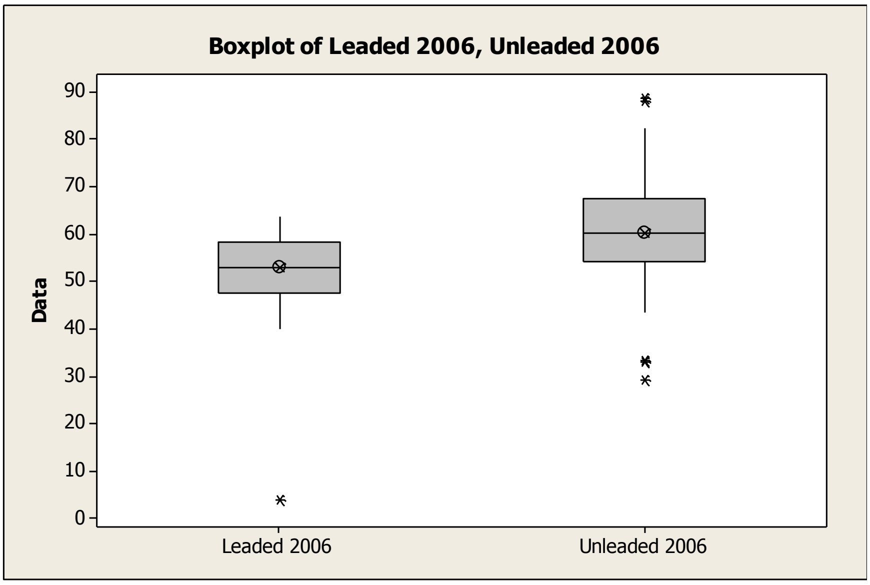
Economic Freedom

Economic Freedom and the Elimination of Leaded Petrol in 2006

In 2006, economic freedom data was available for the following countries which continued to use lead additives in their vehicular fuel: Algeria, Bosnia-Herzegovina, Egypt, Jordan, Kazakhstan, North Korea, Macedonia, Morocco, Myanmar, Serbia, Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for Afghanistan, Iraq, Palestine or Western Sahara. The Economic Freedom Index for 2006 assessed the economic freedom levels of 157 countries throughout the world (The Heritage Foundation 2006).



Visual comparative analysis of the frequency histogram generated by the data contained in the Economic Freedom Index 2006 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher economic freedom values than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of high levels of economic freedom), while the countries which had not eliminated lead from their vehicular fuel fell closer to the centre of the histogram. The outlying leaded country returning an economic freedom value of 4.0 was North Korea.



Median of Leaded 2006

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Median of Leaded 2006 = 52.9
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Median of Unleaded 2006

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Median of Unleaded 2006 = 60.3
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A box plot of the median values of each of the datasets indicated that the median economic freedom value for countries that continued to use leaded petrol in 2006 was 52.9, while the median economic freedom value for countries that had eliminated leaded petrol in 2006 was 60.3. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2006, Unleaded 2006

```
                  N  Median
Leaded 2006      14   52.90
Unleaded 2006   143   60.30


Point estimate for ETA1-ETA2 is -7.90
95.0 Percent CI for ETA1-ETA2 is (-13.70,-2.80)
W = 610.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0023
The test is significant at 0.0023 (adjusted for ties)
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A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0023, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that a relationship existed between economic freedom values and the elimination or non-elimination of leaded additives from vehicular fuel. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower economic freedom values and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2006

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
14	0	50.0071	14.7152	52.9	4	63.7	-2.61425	8.05467

Box-Cox transformation: Lambda = 2

Johnson transformation function:
0.187437 + 0.486055 * Asinh((X - 55.0131) / 2.35085)

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	1.416	<0.005	
Box-Cox Transformation	0.515	0.158	
Lognormal	3.140	<0.005	
3-Parameter Lognormal	1.401	*	0.000
Exponential	3.873	<0.003	
2-Parameter Exponential	3.998	<0.010	0.611
Weibull	1.729	<0.010	
3-Parameter Weibull	0.449	0.175	0.000
Smallest Extreme Value	0.445	>0.250	
Largest Extreme Value	2.219	<0.010	
Gamma	2.670	<0.005	
3-Parameter Gamma	1.568	*	0.001
Logistic	0.721	0.033	
Loglogistic	2.027	<0.005	
3-Parameter Loglogistic	0.730	*	0.000
Johnson Transformation	0.194	0.870	

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	50.00714		14.71517	
Box-Cox Transformation*	2701.78357		1022.17356	
Lognormal*	3.78816		0.70261	
3-Parameter Lognormal	7.99940		0.00479	-2929.11926
Exponential			50.00714	
2-Parameter Exponential			49.54615	0.46099
Weibull		4.19397	53.73403	
3-Parameter Weibull		323.05634	2513.06776	-2457.79698
Smallest Extreme Value	55.25826		7.75131	
Largest Extreme Value	41.61368		20.27219	
Gamma		4.19150	11.93060	
3-Parameter Gamma		355.32304	0.80836	-237.53923
Logistic	52.59764		6.11594	
Loglogistic	3.93935		0.21633	
3-Parameter Loglogistic	7.89015		0.00230	-2618.23208
Johnson Transformation*	-0.06720		0.83862	

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a Johnson transformation probability distribution provided the best fit, returning a p value of 0.870. This indicated that the best fit for the dataset would be the non-normal probability distribution generated by a Johnson transformation.

The probability distribution diagnosis also identified that a smallest extreme value probability distribution with a location parameter of 55.25826 and a scale parameter of 7.75131 provided a good fit for the data, returning a p value greater than 0.500. This result was substantially above the assigned α risk of 0.05.

While the Johnson transformation provided the most appropriate probability distribution for the leaded dataset, and would therefore have returned the most accurate statistical data, the high p value associated with the identified smallest extreme value probability distribution meant that this also met the criteria for acceptance (p value ≥0.05) and was also suitable.

The generation of a non-normal dataset through the application of a Johnson transformation would have required complex statistical analysis. Given that a smallest extreme value probability distribution was also identified as meeting the criteria for acceptance and providing a good fit for the data, the benefits of utilising a probability distribution generated by the performance of a Johnson transformation were outweighed by the complexities of the process. Consequently, the identified smallest extreme value probability distribution of the leaded dataset was used to test the substantiveness of the statistical difference that was present in the two datasets.

Cumulative Distribution Function

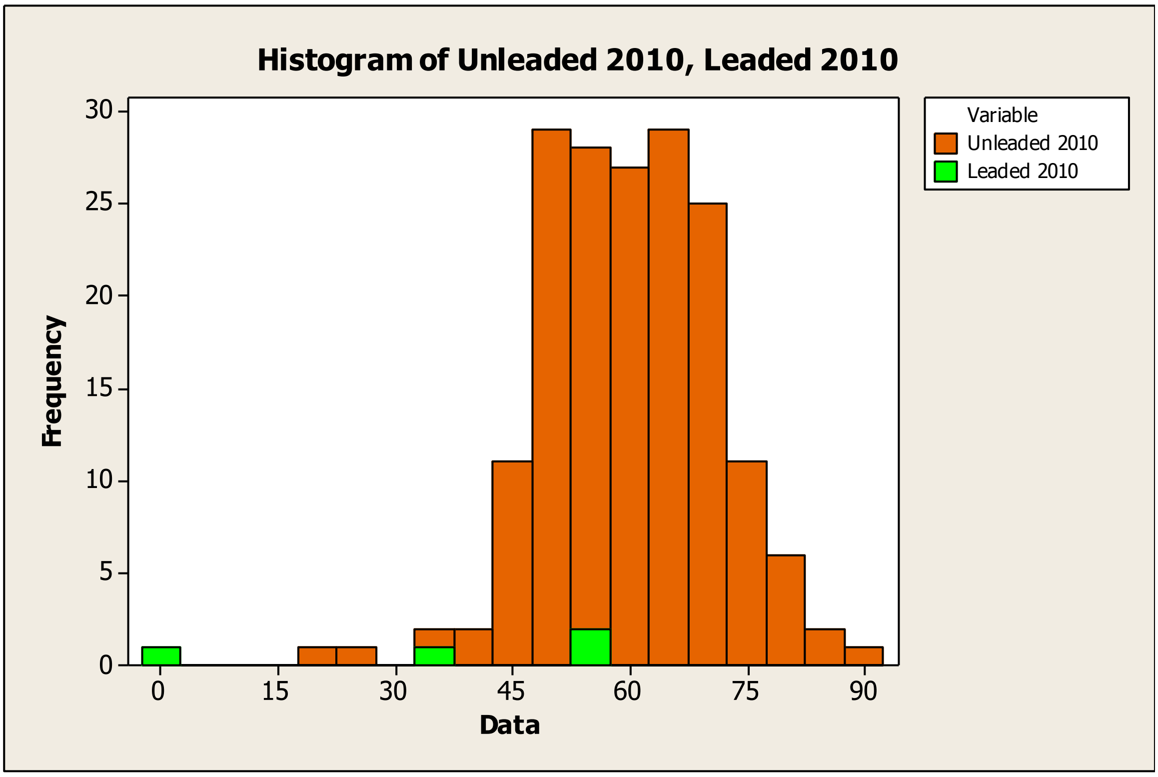
```
Smallest Extreme Value with location = 55.2583 and scale = 7.75131

   x  P( X <= x )
60.3     0.852861
```

A cumulative distribution function of the identified smallest extreme value probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was an 85.3% chance that a leaded country would have an economic freedom value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having an economic freedom value greater than or equal to the average economic freedom level of unleaded countries was 14.7%. From this analysis, it can be concluded not only that a significant difference existed in the economic freedom values of leaded and unleaded countries in 2006, but also that the practical difference in economic freedom levels between the two was substantial.

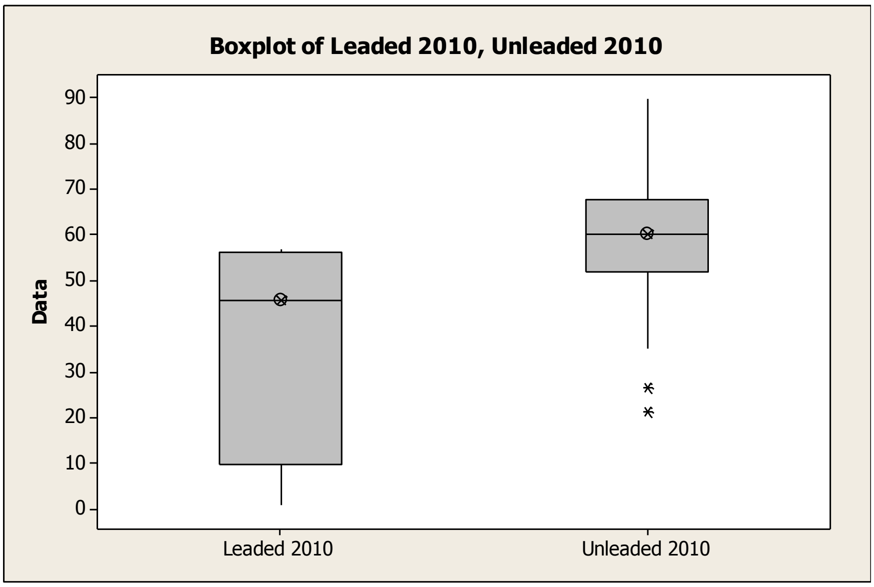
From these findings, it can be confidently asserted that the likelihood that a country was leaded was related to its level of economic freedom, and that leaded countries were substantially less likely to exhibit high levels of economic freedom than unleaded countries. While it is not possible in the absence of comparable time series data to definitively state that the relationship between low economic freedom levels and continuing use of leaded vehicular fuel was causative in nature, it is clear that a close relationship between the two existed. These findings provide strong support for the proposition that failures to address the low levels of economic freedom present in countries that continued to rely on leaded petrol may have been inhibiting the global effort to eliminate lead additives from vehicular fuel in 2006.

Economic Freedom and the Elimination of Leaded Petrol in 2010

In 2010, economic freedom data was available for the following countries which continued to use lead additives in their vehicular fuel: Algeria, Myanmar, North Korea and Yemen. Data was not available for Afghanistan or Iraq. The extremely small sample size associated with the leaded dataset limits the reliability of any analysis that can be conducted in relation to economic freedom data in 2010. The Economic Freedom Index for 2010 assessed the economic freedom levels of 180 countries throughout the world (The Heritage Foundation 2010).



Visual comparative analysis of the frequency histogram generated by the data contained in the Economic Freedom Index 2010 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher economic freedom values than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of high levels of economic freedom), while the countries which had not eliminated lead from their vehicular fuel were spread more evenly along the histogram. The outlying countries in the unleaded dataset were Zimbabwe and Cuba, while the outlying leaded country was North Korea.



Median of Leaded 2010

```
Median of Leaded 2010 = 45.55
```

Median of Unleaded 2010

```
Median of Unleaded 2010 = 60
```

A box plot of the median values of each of the datasets indicated that the median economic freedom value for countries that continued to use leaded petrol in 2010 was 45.55, while the median economic freedom value for countries that had eliminated leaded petrol in 2010 was 60. The box plot therefore revealed a difference in the median values of the datasets – greater than the difference observed in the 2006 datasets – providing strong support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2010, Unleaded 2010

```
                 N  Median
Leaded 2010      4   45.55
Unleaded 2010  175   60.00


Point estimate for ETA1-ETA2 is -15.90
95.1 Percent CI for ETA1-ETA2 is (-47.82,-1.79)
W = 140.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0326
The test is significant at 0.0326 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0326, which was below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that, as in 2006, a relationship existed between economic freedom values and the elimination or non-elimination of leaded additives from vehicular fuel in 2010. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between lower levels of economic freedom and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2010

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
4	0	37.25	25.7851	45.55	1	56.9	-1.36118	1.29734

Box-Cox transformation: Lambda = 1

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.368	0.223	
Box-Cox Transformation	0.368	0.223	
Lognormal	0.657	0.025	
3-Parameter Lognormal	1.774	*	0.602
Exponential	0.772	0.162	
2-Parameter Exponential	0.855	0.041	1.000
Weibull	0.783	0.028	
3-Parameter Weibull	3.298	<0.005	1.000
Smallest Extreme Value	0.404	>0.250	
Largest Extreme Value	0.471	0.209	
Gamma	0.705	0.081	
3-Parameter Gamma	1.810	*	1.000
Logistic	0.391	>0.250	
Loglogistic	0.717	0.027	
3-Parameter Loglogistic	1.195	*	0.392

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	37.25000		25.78507	
Box-Cox Transformation*	37.25000		25.78507	
Lognormal*	2.91011		1.95005	
3-Parameter Lognormal	6.68666		0.02817	-781.86328
Exponential			37.25000	
2-Parameter Exponential			48.33260	-11.08315
Weibull		1.01828	37.43323	
3-Parameter Weibull		53.16938	834.78611	-803.75228
Smallest Extreme Value	47.30201		15.42541	
Largest Extreme Value	25.33804		23.31823	
Gamma		0.83424	44.65166	
3-Parameter Gamma		1389.89073	0.60332	-818.55829
Logistic	40.41322		13.07434	
Loglogistic	3.26995		0.92868	
3-Parameter Loglogistic	6.67972		0.01664	-771.39027

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified a number of probability distributions that fit the dataset, returning p values greater than 0.05. The best fits identified by the probability diagnosis were a smallest extreme value probability distribution with a location parameter of 47.30201 and a scale parameter of 15.42541, and a logistic probability distribution with a location parameter of 40.41322 and a scale parameter of 13.07434. Both probability distributions returned a p value of >0.250. As it was impossible to determine – on the basis of the returned p values – which probability distribution best fit the data, a cumulative distribution function was performed on each of the identified probability distributions. By this method, it was possible to conclude, with 95% confidence, that the likelihood that a leaded country would have an economic freedom value lower than or equal to the median economic freedom value of the unleaded countries would fall somewhere between the two values returned by the cumulative distribution functions respectively.

Cumulative Distribution Function

```
Logistic with location = 40.4132 and scale = 13.0743

 x  P( X <= x )
60     0.817292
```

Cumulative Distribution Function

```
Smallest Extreme Value with location = 47.3020 and scale = 15.4254

 x  P( X <= x )
60     0.897485
```

A cumulative distribution function of the identified logistic probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was an 81.7% chance that a leaded country would have an economic freedom value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having an economic freedom value greater than or equal to the median economic freedom level of unleaded countries was 18.3%.

A cumulative distribution function of the identified smallest extreme value probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was an 89.7% chance that a leaded country would have an economic freedom value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having an economic freedom value greater than or equal to the median economic freedom level of unleaded countries was 10.3%.

Regardless of which probability distribution is preferred, it is clear that it was more than four times more likely that a leaded country would have an economic freedom value below or equal to the median economic freedom value of the unleaded countries. Under either test, it was clear that the difference in the leaded and unleaded datasets in relation to economic freedom values is 2010 was of significant practical effect.

From this result, it can be concluded not only that a significant difference existed in the economic freedom values of leaded and unleaded countries in 2010, but also that the practical difference in economic freedom levels between the two was substantial.

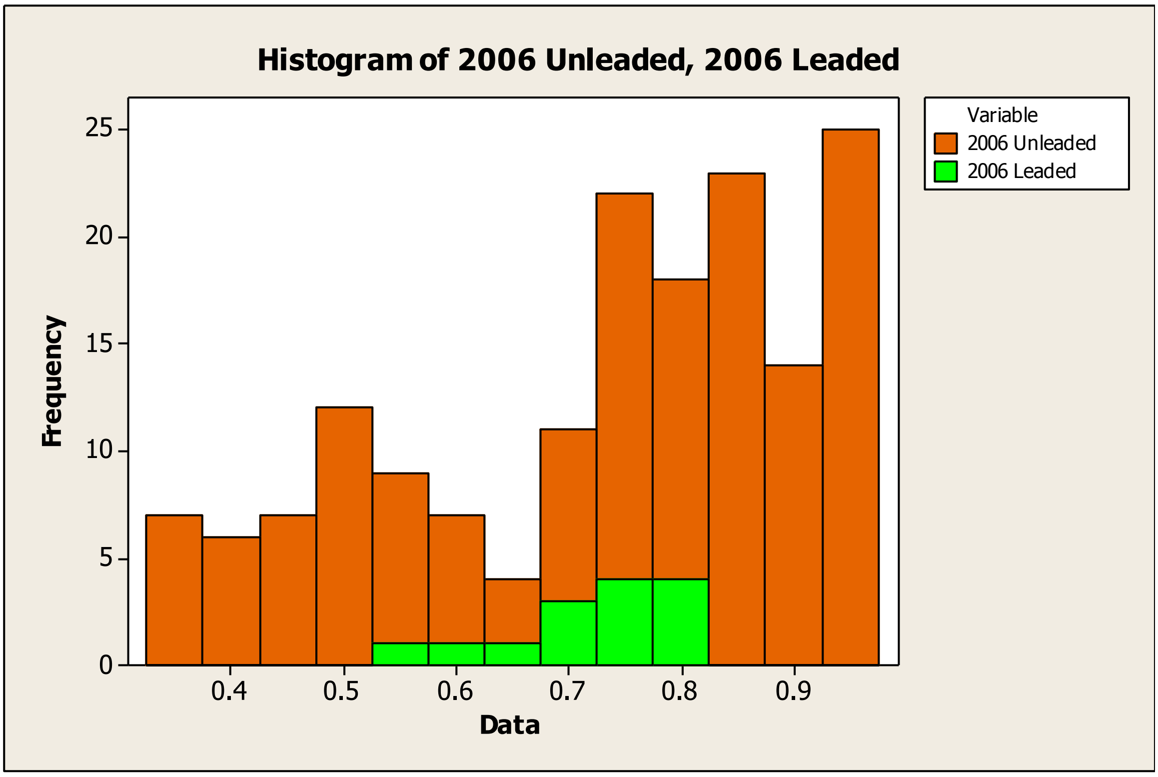
From these findings, it can be confidently asserted that the likelihood that a country is leaded is related to its level of economic freedom, and that the relationship between economic freedom levels and the elimination of leaded petrol operated throughout the period 2006 to 2010. It is clear that leaded countries are substantially less likely to exhibit higher levels of economic freedom than unleaded countries.

While in the absence of comparable time series data no definitive statement can be made as to whether the relationship between low levels of economic freedom and an increased tendency towards reliance on leaded fuel is causative in nature, the strength of the relationship provides considerable support for the proposition that failures to address low economic freedom levels in countries that continue to rely on leaded petrol may be inhibiting the global effort to eliminate lead additives from vehicular fuel.

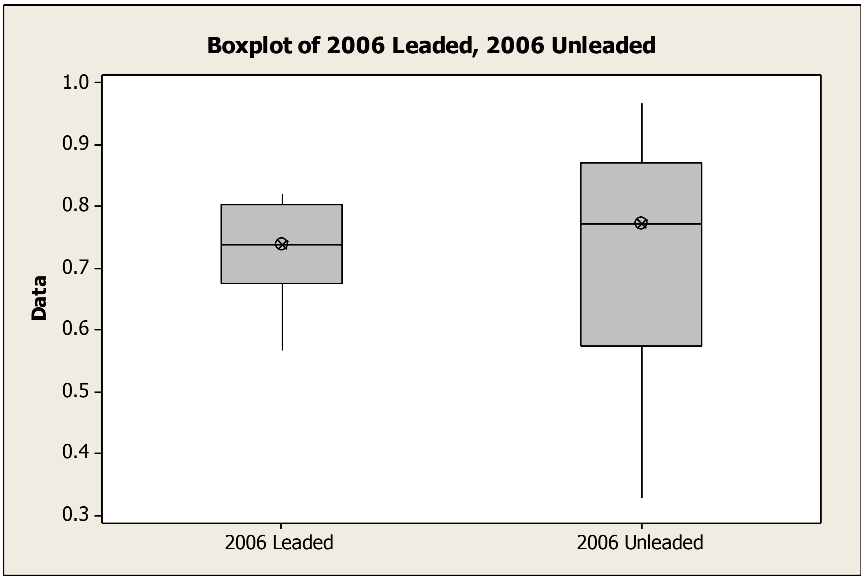
Human Development

<u>Human Development and the Elimination of Leaded Petrol in 2006</u>

In 2008, human development data relating to 2006 was available for the following countries which continued to use lead additives in their vehicular fuel: Algeria, Bosnia-Herzegovina, Egypt, Jordan, Kazakhstan, Macedonia, Morocco, Myanmar, Palestine, Serbia, Tajikistan, Tunisia, Turkmenistan, Uzbekistan and Yemen. Data was not available for Afghanistan, Iraq, North Korea or Western Sahara. The Human Development Index for 2008 (which reported on 2006 data) assessed the human development levels in 179 countries throughout the world (United Nations Development Programme 2008b).



Visual comparative analysis of the frequency histogram generated by the data contained in the Human Development Index 2006 indicated that while more countries which had eliminated lead from vehicular fuel displayed higher human development values than countries which had not eliminated lead, more countries which had eliminated lead also displayed lower human development values than those which had not. Both datasets were spread fairly evenly along the histogram, with both datasets tending towards higher human development values.



Median of 2006 Leaded

```
Median of 2006 Leaded = 0.738
```

Median of 2006 Unleaded

```
Median of 2006 Unleaded = 0.771
```

A box plot of the median values of each of the datasets indicated that the median human development value for countries that continued to use leaded petrol in 2006 was 0.738, while the median human development value for countries that had eliminated leaded petrol in 2006 was 0.771. The box plot therefore revealed a slight difference in the median values of the datasets, warranting further investigation into the relationship between the two datasets through the testing for statistical significance.

Mann-Whitney Test and Confidence Interval: 2006 Leaded, 2006 Unleaded

```
                  N   Median
2006 Leaded      14  0.73800
2006 Unleaded   165  0.77100


Point estimate for ETA1-ETA2 is -0.03500
95.0 Percent CI for ETA1-ETA2 is (-0.11196,0.04998)
W = 1088.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.3569
The test is significant at 0.3569 (adjusted for ties)
```

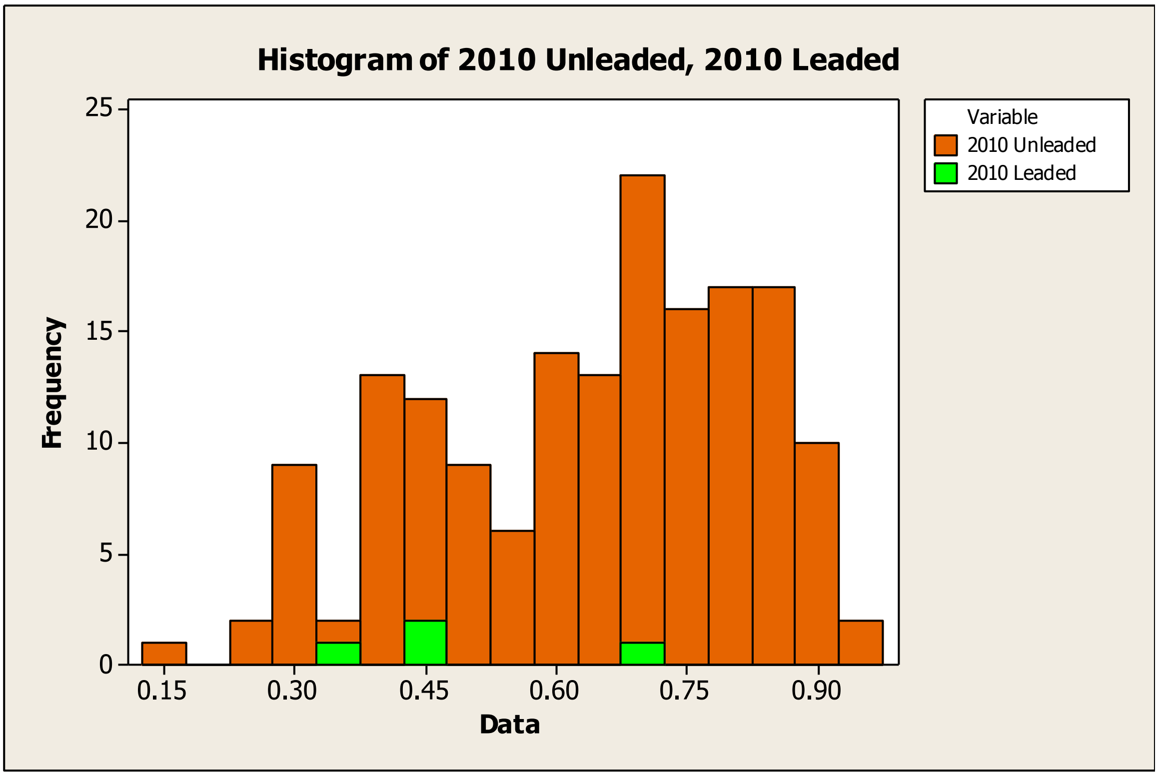
A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.359, which was well above the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was accepted, and the alternate hypothesis that a statistically significant difference existed between the two datasets was rejected.

From the finding that the datasets were statistically equal, it was possible to conclude with confidence that any relationship which may have been observed between economic freedom values and a failure to eliminate leaded petrol in 2006 (e.g. in the histograms or box plots generated by the data) emerged by chance.

The finding that no such correlation exists between the factors makes it possible to conclude with confidence there was no causative relationship between a country's human development levels and its status in relation to the elimination of leaded vehicular fuel. It was therefore possible to conclude with confidence that the human development levels that were present in countries still reliant on leaded petrol was not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel in 2006.

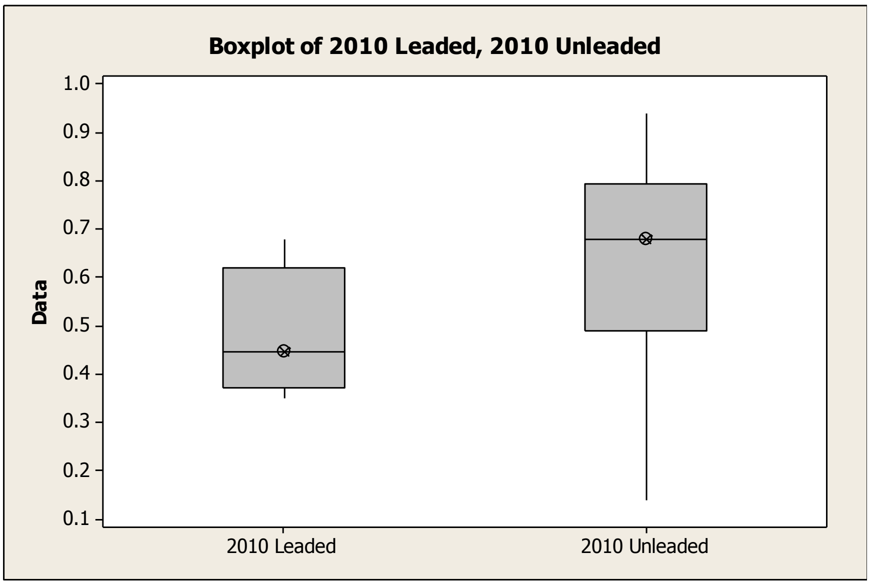
Human Development and the Elimination of Leaded Petrol in 2010

In 2010, human development data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Myanmar, and Yemen. Data was not available for Iraq or North Korea. The extremely small sample size associated with the leaded dataset limits the reliability of any analysis that can be conducted in relation to human development data in 2010. The Human Development Index for 2010 assessed the human development levels of 169 countries throughout the world (United Nations Human Development Programme 2010).



Visual comparative analysis of the frequency histogram generated by the data contained in the Human Development Index 2010 indicated that more countries which had eliminated lead from their vehicular fuel displayed higher human development values than countries which had not eliminated lead from their vehicular fuel.

A majority of countries which had eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of high levels of human development), while the countries which had not eliminated lead from their vehicular fuel were more evenly spread across the histogram, tending towards the left (indicative of low levels of human development). The leaded country falling to the right of the histogram was Algeria, the only country in the leaded dataset to have committed to a phase-out date for the elimination of lead additives in vehicular fuel (UNEP PCFV 2011: 7).



Median of 2010 Leaded

```
Median of 2010 Leaded = 0.445
```

Median of 2010 Unleaded

```
Median of 2010 Unleaded = 0.679
```

A box plot of the median values of each of the datasets indicated that the median human development value for countries that continued to use leaded petrol in 2010 was 0.445, while the median human development value for countries that had eliminated leaded petrol in 2010 was 0.679. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: 2010 Leaded, 2010 Unleaded

```
                  N  Median
2010 Leaded       4  0.4450
2010 Unleaded   165  0.6790


Point estimate for ETA1-ETA2 is -0.1850
95.1 Percent CI for ETA1-ETA2 is (-0.3611,0.0229)
W = 175.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0899
The test is significant at 0.0899 (adjusted for ties)
```

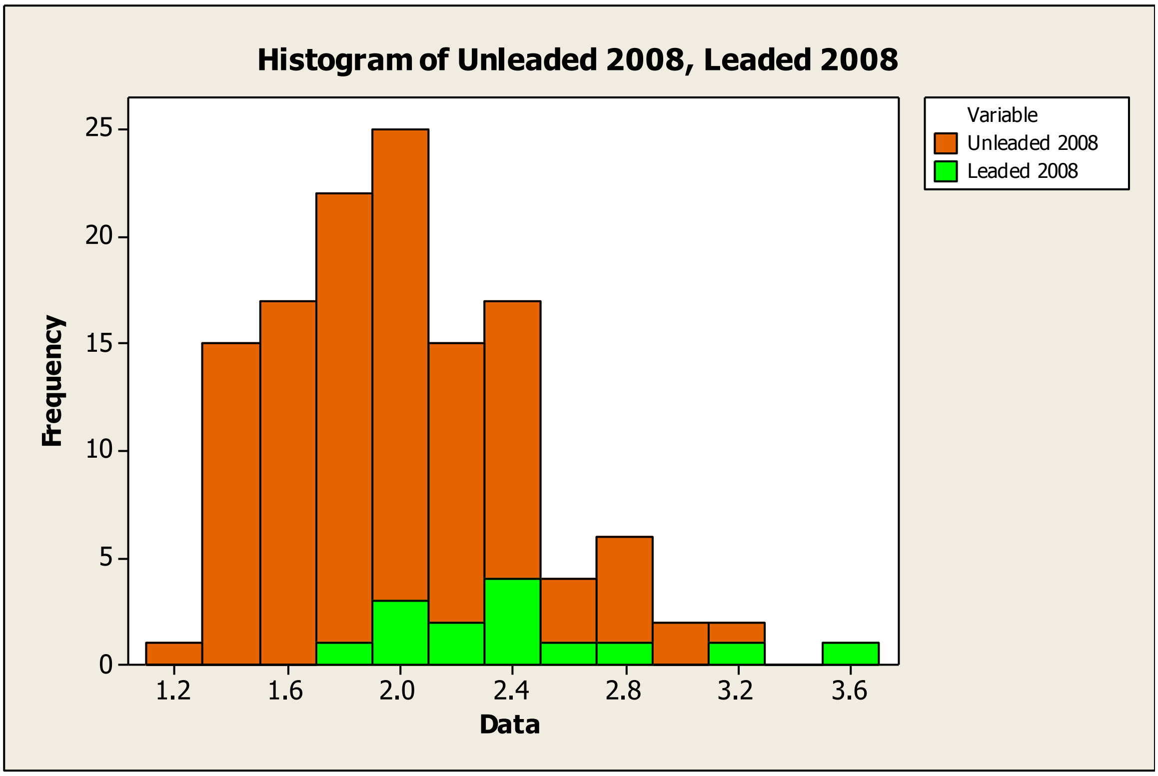
A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0899, which was above the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was accepted, and the alternate hypothesis that a statistically significant difference existed between the two datasets was rejected.

From the finding that the datasets were statistically equal, it was possible to conclude with confidence that any relationship which may have been observed between human development values and a failure to eliminate leaded petrol in 2010 (e.g. in the histograms or box plots generated by the data) emerged by chance. The absence of a correlation between a country's human development levels and status in relation to the elimination of leaded fuel denies the possibility of a causal relationship between the factors. Consequently, it is possible to conclude that, as in 2006, the lower levels of human development observable in leaded countries as compared with their unleaded counterparts (illustrated in the histogram and box plot generated by the data) were not acting as a barrier to the elimination of lead additives from vehicular fuel in 2010. We can conclude with confidence that there is no causative relationship between human development levels and the elimination of lead additives from vehicular fuel, and therefore that the human development levels present in countries reliant on leaded petrol is not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel.

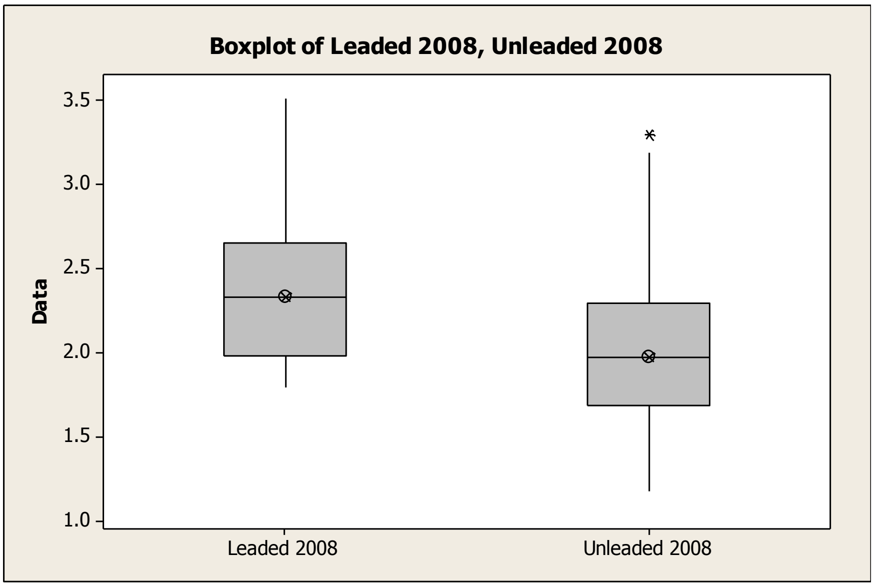
Peacefulness

Peacefulness and the Elimination of Leaded Petrol in 2008

In 2008, peacefulness data was available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Bosnia-Herzegovina, Egypt, Iraq, North Korea, Macedonia, Morocco, Myanmar, Serbia, Tunisia, Turkmenistan, Uzbekistan and Yemen (Taylor 2008; Vision for Humanity 2008). Data was not available for Kosovo, Montenegro, Tajikistan or Western Sahara (Taylor 2008; Vision for Humanity 2008). The Global Peace Index for 2008 assessed the peace levels of 140 countries throughout the world (Vision for Humanity 2008).



Visual comparative analysis of the frequency histogram generated by the data contained in the Global Peace Index 2008 indicated that more countries which had eliminated lead from their vehicular fuel displayed lower peace values (indicative of higher levels of peace) than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of high levels of peacefulness), while the countries which had not eliminated lead from their vehicular fuel were spread more evenly along the histogram, with a tendency to fall to the right of the histogram (indicative of low levels of peacefulness). The leaded country exhibiting the lowest levels of peacefulness in 2008 was Iraq.



Median of Leaded 2008

```
Median of Leaded 2008 = 2.327
```

Median of Unleaded 2008

```
Median of Unleaded 2008 = 1.975
```

A box plot of the median values of each of the datasets indicated that the median peacefulness value for countries that continued to use leaded petrol in 2008 was 2.327, while the median peacefulness value for countries that had eliminated leaded petrol in 2008 was 1.975. The box plot therefore revealed a difference in the median values of the datasets, and provided support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and Confidence Interval: Leaded 2008, Unleaded 2008

```
                 N  Median
Leaded 2008     14  2.3270
Unleaded 2008  126  1.9750


Point estimate for ETA1-ETA2 is 0.3490
95.0 Percent CI for ETA1-ETA2 is (0.1080,0.6079)
W = 1384.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0059
The test is significant at 0.0059 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0059, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it was possible to conclude with confidence that a relationship existed between peacefulness values and the elimination or non-elimination of leaded additives from vehicular fuel. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicated that the relationship between higher peacefulness values (indicative of lower levels of peacefulness) and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2008

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
14	0	2.38786	0.487944	2.327	1.797	3.514	1.13750	0.857149

Box-Cox transformation: Lambda = -2

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.572	0.114	
Box-Cox Transformation	0.191	0.876	
Lognormal	0.368	0.378	
3-Parameter Lognormal	0.189	*	0.123
Exponential	4.351	<0.003	
2-Parameter Exponential	0.746	0.124	0.000
Weibull	0.701	0.058	
3-Parameter Weibull	0.266	>0.500	0.016
Smallest Extreme Value	0.975	0.011	
Largest Extreme Value	0.279	>0.250	
Gamma	0.445	>0.250	
3-Parameter Gamma	0.221	*	0.057
Logistic	0.465	0.199	
Loglogistic	0.330	>0.250	
3-Parameter Loglogistic	0.199	*	0.140

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	2.38786		0.48794	
Box-Cox Transformation*	0.19340		0.06574	
Lognormal*	0.85264		0.19166	
3-Parameter Lognormal	-0.42932		0.61131	1.60889
Exponential			2.38786	
2-Parameter Exponential			0.63631	1.75155
Weibull		5.01537	2.58714	
3-Parameter Weibull		1.70771	0.84846	1.63563
Smallest Extreme Value	2.64328		0.53960	
Largest Extreme Value	2.17906		0.33698	
Gamma		28.32307	0.08431	
3-Parameter Gamma		1.40775	0.43476	1.77583
Logistic	2.32638		0.25952	
Loglogistic	0.83547		0.10560	
3-Parameter Loglogistic	-0.54098		0.40390	1.67350

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a Box-Cox transformation probability distribution provided the best fit, returning a p value of 0.876. This indicated that the best fit for the dataset would be the normal probability distribution generated by a Box-Cox transformation.

The probability distribution diagnosis also identified that a 3-parameter Weibull probability distribution with a shape parameter of 1.70771, scale parameter of 0.84846 and threshold parameter of 1.63563 provided a good fit for the data, returning a p value greater than 0.500. This result was substantially above the assigned α risk of 0.05.

While the Box-Cox transformation provided the most appropriate probability distribution for the leaded dataset, and would therefore have returned the most accurate statistical data, the high p value associated with the identified 3-parameter Weibull distribution meant that this also met the criteria for acceptance (p value ≥0.05) and was also suitable.

The generation of a normal dataset through the application of a Box-Cox transformation would have required complex statistical analysis. Given that a 3-parameter Weibull probability distribution was also identified as meeting the criteria for acceptance and providing a good fit for the data, the benefits of utilising a probability distribution generated by the performance of a Box-Cox transformation were outweighed by the complexities of the process. Consequently, the identified 3-parameter Weibull distribution of the leaded dataset was used to test the substantiveness of the statistical difference that was present in the two datasets.

Cumulative Distribution Function

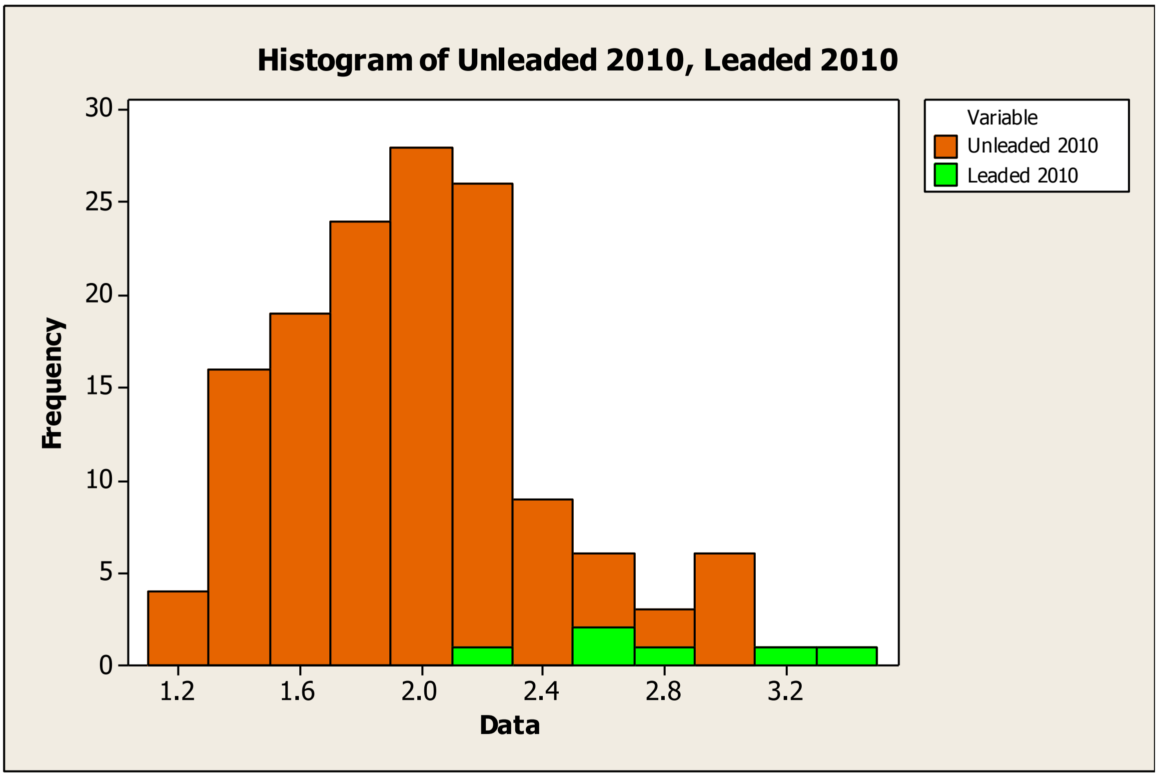
```
Weibull with shape = 1.70771 and scale = 0.84846 and threshold = 1.63563

    x  P( X <= x )
1.975     0.188705
```

A cumulative distribution function of the identified 3-parameter Weibull probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was an 18.9% chance that a leaded country would have a peacefulness value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a peacefulness value greater than or equal to the median peacefulness level of unleaded countries was 81.1%. From this analysis, it can be concluded not only that a significant difference existed in the peacefulness values of leaded and unleaded countries in 2008, but also that the practical difference in peacefulness levels between the two was substantial.

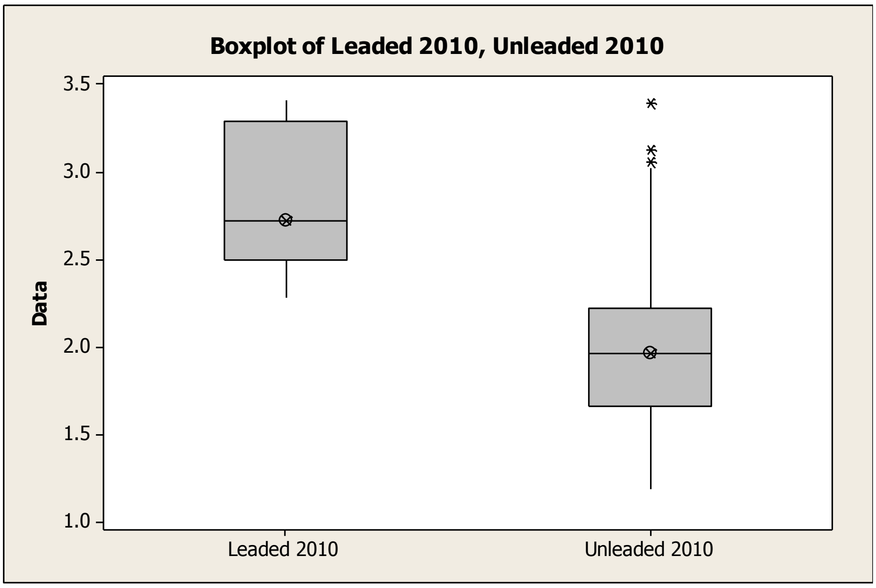
Recalling that lower peacefulness values denoted higher levels of peacefulness, it can be confidently asserted from these findings that in 2008 the likelihood that a country was leaded was related to its level of peacefulness, and that leaded countries were substantially less likely to be as peaceful as unleaded countries. While it is not possible in the absence of comparable time series data to definitively state that the relationship between low peacefulness levels and continuing use of leaded vehicular fuel was causative in nature, it is clear that a close relationship between the two existed. These findings provide strong support for the proposition that failures to address the low levels of peacefulness present in countries that continued to rely on leaded petrol may have been inhibiting the global effort to eliminate lead additives from vehicular fuel in 2008.

Peacefulness and the Elimination of Leaded Petrol in 2010

In 2010, peacefulness values were available for the following countries which continued to use lead additives in their vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen. The Global Peace Index for 2010 assessed the peacefulness levels of 149 countries throughout the world (Vision for Humanity 2010).



Visual comparative analysis of the frequency histogram generated by the data contained in the Global Peace Index 2010 indicated that more countries which had eliminated lead from their vehicular fuel displayed lower peacefulness values (indicative of higher levels of peacefulness) than countries which had not eliminated lead from their vehicular fuel. A majority of countries which had eliminated lead from their vehicular fuel fell to the left of the histogram (indicative of high levels of peacefulness), while the majority of countries which had not eliminated lead from their vehicular fuel fell to the right of the histogram (indicative of low levels of peacefulness). This visual comparative analysis of the datasets suggested that the relationship between peacefulness values and the continued use/elimination of lead additives may have been more prominent in 2010 than it was in 2008.



Median of Leaded 2010

```
Median of Leaded 2010 = 2.7175
```

Median of Unleaded 2010

```
Median of Unleaded 2010 = 1.964
```

A box plot of the median values of each of the datasets indicated that the median peacefulness value for countries that continued to use leaded petrol in 2010 was 2.7175, while the median peacefulness value for countries that had eliminated leaded petrol in 2010 was 1.964. The box plot therefore revealed a difference in the median values of the datasets, greater than the difference observed in the 2008 datasets, providing strong support for the proposition that the median values of the two datasets were sufficiently far apart to warrant a test for statistical significance.

Mann-Whitney Test and CI: Leaded 2010, Unleaded 2010

```
                 N  Median
Leaded 2010      6  2.7175
Unleaded 2010  143  1.9640


Point estimate for ETA1-ETA2 is 0.8480
95.1 Percent CI for ETA1-ETA2 is (0.4650,1.2259)
W = 812.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0005
The test is significant at 0.0005 (adjusted for ties)
```

A Mann-Whitney test on the two datasets with a confidence interval of 95% returned a p value of 0.0005, which was substantially below the assigned α risk of 0.05. Consequently, the null hypothesis that the two datasets were statistically equal was rejected, and the alternate hypothesis that a statistically significant difference existed between the two datasets was accepted.

From the finding of a statistically significant difference between the two datasets, it is possible to conclude with confidence that, as in 2008, a relationship existed between peacefulness values and the elimination or non-elimination of leaded additives from vehicular fuel in 2010. The finding of the statistical significance of the difference between the datasets for leaded and unleaded countries indicates that the relationship between higher peacefulness values (indicative of lower levels of peacefulness) and a failure to eliminate lead from vehicular fuel (evident in the frequency histogram of the two datasets) did not emerge by chance.

Distribution ID Plot for Leaded 2010

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
6	0	2.82383	0.434653	2.7175	2.277	3.406	0.299704	-1.43743

Box-Cox transformation: Lambda = -0.400408

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	0.262	0.552	
Box-Cox Transformation	0.236	0.646	
Lognormal	0.241	0.624	
3-Parameter Lognormal	0.269	*	0.772
Exponential	2.063	0.005	
2-Parameter Exponential	0.694	0.091	0.000
Weibull	0.335	>0.250	
3-Parameter Weibull	0.321	0.461	0.685
Smallest Extreme Value	0.365	>0.250	
Largest Extreme Value	0.266	>0.250	
Gamma	0.294	>0.250	
3-Parameter Gamma	0.541	*	1.000
Logistic	0.297	>0.250	
Loglogistic	0.276	>0.250	
3-Parameter Loglogistic	0.257	*	0.681

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	2.82383		0.43465	
Box-Cox Transformation*	0.66355		0.04066	
Lognormal*	1.02827		0.15345	
3-Parameter Lognormal	0.18105		0.32456	1.56212
Exponential			2.82383	
2-Parameter Exponential			0.65620	2.16763
Weibull		7.87153	2.99985	
3-Parameter Weibull		5.45963	2.10949	0.87495
Smallest Extreme Value	3.02545		0.36987	
Largest Extreme Value	2.63133		0.33556	
Gamma		51.03904	0.05533	
3-Parameter Gamma		305.03833	0.02265	-4.21032
Logistic	2.80507		0.24295	
Loglogistic	1.02478		0.08565	
3-Parameter Loglogistic	-0.11065		0.26527	1.85578

* Scale: Adjusted ML estimate

A probability distribution diagnosis performed on the leaded dataset identified that a Box-Cox transformation probability distribution provided the best fit, returning a p value of 0.646. This indicated that the best fit for the dataset would be the normal probability distribution generated by a Box-Cox transformation.

The probability distribution diagnosis also identified that a lognormal probability distribution with a location parameter of 1.02827 and a scale parameter of 0.15345 provided a good fit for the data, returning a p value of 0.624. This result was substantially above the assigned α risk of 0.05.

While the Box-Cox transformation provided the most appropriate probability distribution for the leaded dataset, and would therefore have returned the most accurate statistical data, the high p value associated with the identified lognormal distribution meant that this also met the criteria for acceptance (p value ≥0.05) and was also suitable.

The generation of a normal dataset through the application of a Box-Cox transformation would have required complex statistical analysis. Given that a lognormal probability distribution was also identified as meeting the criteria for acceptance and providing a good fit for the data, the benefits of utilising a probability distribution generated by the performance of a Box-Cox transformation were outweighed by the complexities of the process. Consequently, the identified lognormal distribution of the leaded dataset was used to test the substantiveness of the statistical difference that was present in the two datasets.

Cumulative Distribution Function

```
Lognormal with location = 1.02827 and scale = 0.15345

    x  P( X <= x )
1.964    0.0106593
```

A cumulative distribution function of the identified lognormal probability distribution of the leaded dataset up to and including the median of the unleaded dataset revealed that there was a 10.1% chance that a leaded country would have a peacefulness value lower than or equal to the median of the unleaded countries. This meant that the likelihood of a leaded country having a peacefulness value greater than or equal to the median peacefulness level of unleaded countries was 89.9%.

Recalling that lower peacefulness values denoted higher levels of peacefulness, from this result, it can be concluded not only that a significant difference existed in the peacefulness values of leaded and unleaded countries in 2010, but also that the practical difference in peacefulness levels between the two was very substantial. Furthermore, this result indicates that the divergence in the peacefulness values of leaded countries as compared with unleaded countries was even greater in 2010 than it was in 2008.

From these findings, it can be confidently asserted that the likelihood that a country is leaded is related to its level of peacefulness, and that the relationship between peacefulness levels and the elimination of leaded petrol operated throughout the period 2008 to 2010. It is clear that leaded countries are substantially less likely to be peaceful than unleaded countries, and as time has progressed this trend has become even more pronounced.

While in the absence of comparable time series data no definitive statement can be made as to whether the relationship between low levels of peacefulness and an increased tendency towards reliance on leaded fuel is causative in nature, the strength of the relationship provides considerable support for the proposition that failures to address low peacefulness levels in countries that continue to rely on leaded petrol may be inhibiting the global effort to eliminate lead additives from vehicular fuel. As the correlation between low peacefulness levels and reliance on leaded petrol became more pronounced in 2010 than it was in 2008, it can be asserted that the need to address the low levels of peacefulness present in leaded countries in order to further the global effort to eliminate lead additives from vehicular fuel was more compelling in 2010 than it was in 2008.

Discussion of Results

Corruption, Democracy and the Elimination of Leaded Vehicular fuel

In 2006, Pellegrini and Gerlagh conducted an extensive literature review canvassing studies dating from the 1960s to the present which have investigated the impacts of democratic institutions and bureaucratic corruption as determinants of national environmental policies. According to Pellegrini and Gerlagh (2006: 332-333), the earliest studies into the impact of democratic institutions on environmental protection policies were conducted in the 1960s and 1970s. The body of literature which emerged from this period was largely cynical about the ability of democratic systems of government to generate policies of reform directed at environmental protection, citing concerns that the privileging of concepts such as the free market and individualism would come at the expense of environmental considerations (e.g. Ehrlich 1968; Hardin 1968; Heilbroner 1974). From the 1980s onwards, as studies of the environmental credentials of Soviet nations and the autocratic dictatorships emerging in Africa, Asia and Latin America came to light, environmental researchers began to advocate for democratic governance as a political system through which economic, social cultural and environmental welfare could be supported (McCloskey 1983; Payne 1995).

Pellegrini and Gerlagh (2006: 333) note that more recent studies have moved away from the exploration of the impact that governmental systems have on environmental policy-making, focusing instead on the role that corruption plays in inhibiting environmental change and undermining environmentalist movements (Damania, Fredriksson & List 2003; Fredriksson & Svensson 2003; Lopez & Mitra 2000). They conclude that body of literature today holds that, as a general rule, democratic governmental systems and institutions are more conducive to the introduction of environmental protection policies than non-democratic ones, and that higher levels of corruption tend to hinder environmental protection and reform.

This study was therefore consistent with the existing body of literature in that it confirmed that both low levels of democracy and high levels of corruption make it substantially more likely that a country will continue to be reliant on leaded vehicular fuel, and provides support for the proposition that failures to address the low levels of democracy and high levels of corruption present in leaded countries may be inhibiting the global effort to eliminate lead additives from vehicular fuel. The relationships between low levels of democracy, high levels of corruption and a failure to eliminate lead additives from vehicular fuel was shown to have been operative in both 2006 and 2010.

Although the absence of comparable time series data precluded the determination of whether the observed relationships were causal or merely correlative, when read in light of the established body of literature, these results are consistent with the proposition that the low levels of democracy and high levels of corruption present in countries still reliant on leaded vehicular fuel are acting as barriers to the global effort to eliminate lead additives from vehicular fuel.

In 2010, it was possible to conclude, with 95% confidence, that there was only a 0.1% chance that a country which had failed to eliminate lead additives from its vehicular fuel would have a democracy level greater than or equal to the median democracy value of the countries which had eliminated leaded petrol. The relationship between low levels of democracy and limited capacity to introduce and implement environmental reform, observed by researchers in various studies, therefore must be considered to hold true in relation to the global effort to eliminate lead additives from vehicular fuel.

In 2010, it was also possible to conclude, with 95% confidence, that countries which had failed to eliminate lead additives from their vehicular fuel were more than 20 times more likely to exhibit levels of corruption higher than or equal to the median corruption level of the countries that had eliminated leaded petrol.

In relation to the results returned for the impact of the corruption variable on the elimination of lead additives from vehicular fuel, there is a substantial body of anecdotal evidence supporting the proposition that high levels of corruption in the countries still reliant on leaded petrol is acting as a significant barrier to the global effort to eliminate lead additives from vehicular fuel.

Innospec Speciality Chemicals is an international speciality chemicals company based in the United States of America with subsidiaries around the world. Innospec is the only company in the world that continues to manufacture tetra ethyl lead (TEL), which is the lead additive used in leaded petrol. Innospec therefore is the sole supplier of lead additives to all of the countries in the world which continue to utilise leaded vehicular fuel: Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen. On 18 March 2010, Innospec pled guilty to defrauding the United Nations and to violating the *Foreign Corrupt Practices Act 1977* (United States of America) in its actions in bribing Iraqi officials to import TEL for addition to vehicular fuel. The United States Department of Justice issued a press release in relation to this matter, which states that:

> Innospec pleaded guilty before U.S. District Judge Ellen Segal Huvelle in the District of Columbia to a 12-count information charging wire fraud in connection with Innospec's payment of kickbacks to the former Iraqi government under the UN Oil for Food Program (OFFP), as well as FCPA violations in connection with bribe payments it made to officials in the Iraqi Ministry of Oil...
>
> According to court documents, from 2000 to 2003, Innospec's Swiss subsidiary, Alcor, was awarded five contracts valued at more than €40 million to sell tetraethyl lead to refineries run by the Iraqi Ministry of Oil under the OFFP. To obtain these contracts, Innospec admitted that Alcor paid or promised to pay at least $4 million in kickbacks to the former Iraqi government. Court documents detail how Alcor inflated the price of the contracts by

approximately 10 percent to cover the cost of the kickbacks before submitting them to the UN for approval, and then falsely characterized the payments on the company's books and records as "commissions" paid to Ousama Naaman, its agent in Iraq.

According to court documents, Innospec also admitted to paying and promising to pay more than $1.5 million in bribes, in the form of cash and travel, to officials of the Iraqi Ministry of Oil to secure sales of tetraethyl lead in Iraq from 2004 to 2008, as well as to paying $150,000 in 2006 to officials in the Iraqi Ministry of Oil to ensure that a competing [unleaded] product to tetraethyl lead was not approved for use in Iraqi refineries. Innospec admitted that the illicit payments were recorded as "commissions" on the basis of false invoices, which were incorporated into the company's books and records (United States Department of Justice 2010: 1 – 9).

On the same day, Innospec's British subsidiary, Innospec Ltd, pled guilty in the in the Southwark Crown Court in London in connection with corrupt payments to Indonesian officials. According to The Guardian, 'Indonesia had intended to phase out TEL and leaded fuel from 1999 but Innospec set up a slush fund to bribe officials to block legislative change until 2006 and prolong its sales there' (Evans 2010: 7). On 18 March 2010, the British Serious Fraud Office issued a press release in relation to the prosecution of Innospec in relation to their activities in Indonesia. The press release stated that:

In order to conduct its business in Indonesia, the company appointed agents to act on its behalf in seeking to win or continue contracts to supply TEL. Between 14 February 2002 and 31 December 2006 (the indictment period), the company paid US$ 11.7 million to its agents. From these commissions, bribes were paid by the agents to staff at the state-owned petroleum refinery, Pertamina, and other public officials who were in a position to favour the company by purchasing orders of TEL.

Payments were made in an attempt to ensure that Pertamina favoured TEL over unleaded alternatives.

The agents acted under the instruction of the company and the commission fees paid were authorised by the company. The company accepts that it knew that a proportion of the commission funds would be used to bribe both Pertamina officials and other public officials at higher regulatory or ministerial levels, with influence over the purchase of TEL.

In addition to commissions, the company also created 'ad hoc' funds. These funds assisted specific or 'one-off' arrangements with particularly influential individuals within Pertamina or at a political level.

One particular fund was structured to protect the interests of the lead based additives industry, whereas in truth and reality, it was no more than a slush fund to corrupt senior officials in various Ministries with the intention of blocking legislative moves to ban or enforce the ban on TEL on environmental grounds and/or seeking a higher level buy-in to continued yearly supplies of TEL to Pertamina.

> The Indonesian Government's intention to go lead-free, initially conceived in 1999, was not realised until 2006 (Serious Fraud Office 2010: 7 – 12).

The results of this study, supported by the wider body of environmental reform literature and read in light of the damning body of anecdotal evidence implicating Innospec (the world's sole supplier of TEL) as taking advantage of corruption in countries still reliant on leaded petrol in order to ensure that their product continued to be imported and added to vehicular fuel, make it possible to conclude that the relationship between high levels of corruption and failures to institute environmental reform which has been observed in the wider body of literature holds true in relation to the specific issue of the global effort to eliminate lead additives from vehicular fuel.

In their 2006 study, Pellegrini and Gerlaghin criticised the trend in the body of literature exploring the impact of various determinants upon environmental reform movements to treat the democracy variable as a separate variable to the corruption variable, suggesting that 'because the two variables are highly correlated...the individual estimation of their effects easily overemphasizes the importance of each variable' (2006: 333). Aiming to redress this, the authors conducted a multiple regression analysis holding corruption and democracy as joint explanatory variables in relation to environmental policies across the world. They found that 'corruption stands out as a substantial and significant determinant of environmental policies, while proxies for democracy have an insignificant impact' (2006: 332). They also noted, however, that 'democracy could affect environmental policy stringency given that countries with a history of democratic rule tend to be less corrupted' (2006: 332).

The aim of this study was to identify which factors may be operating to inhibit the global effort to eliminate lead additives from vehicular fuel; it did not aim to provide an assessment of the extent to which individual factors are operating to constrain change. Consequently, this study considered the democracy and corruption variables as separate, independent factors. Further research, replicating the study conducted by Pellegrini and Gerlaghin, could build on the findings of this paper to determine the extent to which each barrier to environmental reform is inhibiting the elimination of lead additives in vehicular fuel in Afghanistan, Algeria, Iraq, Myanmar, North Korea and Yemen respectively. This would enable policy developers to focus on the most salient factors in constructing national plans to eliminate leaded petrol from each country.

Freedom of Information and the Eliminated of Leaded Vehicular fuel

Arthur P. J. Mol's 'Environmental Reform in the Information Age: The Contours of Informational Governance', published in 2008, provides a comprehensive overview of the body of literature surrounding the role of freedom of information on the ability of advocates for environmental reform to have their agenda heard and acted upon by policy-makers. According to Mol, the success of environmental movements and non-governmental organisations from their emergence in the 1960s is attributable in large part to their recognition of the power of information to institute social and environmental change:

> [C]ompared to the other actors in contemporary informational politics and governance, environmentalists were much earlier and for a long time more advanced and concentrated on informational resources....In all, environmental NGOs have been better and especially much earlier aware of the importance of reputation, legitimacy, media coverage, trust and the use of symbols than the later actors in informational governance: state agencies, the private sector and the 'old' social movement actors...(2008: 190-191)

Environmental reform literature provides support for the proposition that countries with higher levels of freedom of information are more likely to have the capacity to introduce and implement reforms directed at environmental protection, holding that higher levels of freedom of information are conducive to increased public participation and civil society involvement, which in turn has positive effects on environmental protection outcomes (Martens 2006: 211). This body of literature was considered to qualify freedom of information as a potential determinant of environmental policy for consideration in this study. While no comprehensive datasets measuring the relative levels of freedom of information available in countries across the world was available, the Press Freedom Index compiled by *Reporters Without Borders* was analysed as a proxy for freedom of information levels across the world.

Results indicated high levels of correlation between press freedom levels and the likelihood that a country had eliminated lead additives from petrol, and provided strong support for the proposition that the lower press freedom levels observable in countries that continued to utilise leaded petrol was acting as a barrier to the global effort to eliminate lead additives from vehicular fuel. Although press freedom can only be considered a proxy for freedom of information, in the context of the wider body of literature supporting the hypothesis that high levels of freedom of information are conducive to the introduction and implementation of environmental reforms, it is reasonable to theorise that the relationship between press freedom and the elimination of leaded petrol is indicative of the broader effect of freedom of information (which will frequently coincide with high levels of press freedom). In this context, the results of this study provides a level of support for the proposition that theorised lower levels of freedom of information in countries that continue to utilise leaded vehicular fuel may be acting as a barrier to the global effort to eliminate leaded petrol.

Economic Factors, Poverty, Human Development and the Elimination of Leaded Vehicular fuel

The wider body of literature investigating the determinants of the success or failure of environmental reforms observes a strong relationship between poverty, economic disadvantage, and national failures to introduce and implement reformative environmental protection policies.

The body of literature in this field focuses on the concept of the Environmental Kuznets Curve, which holds that the inverted U-shape first observed by Simon Kuznets in 1995 to describe the relationship between inequality and income can also be used to describe the relationship between pollution and income (Levinson 2008; Shafik and Bandyopadhyay 1992; Harbaugh et al. 2002). The Environmental Kuznets Curve literature is epitomised in the work of Grossman and Krueger in 1995, who argue that pollution outputs increase as a country embarks on the economic development process, but that this environmental deterioration is followed by a 'subsequent phase of improvement' (1995: 353) in environmental outcomes once a certain level of per capita income is achieved. Application of the Environmental Kuzets Curve literature to the issue of the elimination of lead additives from vehicular fuel predicts that countries with a per capita gross domestic product below a determined critical point (estimated by Grossman and Kruger to be USD$8,000.00, but this figure varies between studies) will emit fewer air pollutants and are therefore more likely to have eliminated lead additives from their vehicular fuel.

While the Environmental Kuznets Curve literature has elicited mixed reactions in the wider academic community (______), the wider body of literature beyond proponents of the Environmental Kuznets Curve concurs with the conclusion that economic factors are a significant determinant of a country's capacity to institute environmental change. In 2005, a cross national study of the determinants of environmental sustainability concluded that 'economic development is the main driver of social and institutional capacity for environmental sustainability' (Husted 2005: 363). Also in 2005, Esty and Porter conducted a cross country statistical analysis of factors driving environmental performance, concluding that '[c]onsistent with the EKC literature, we find a significant correlation between income and environmental performance' (2005: 393).

From this wider body of literature it is evident that, regardless of limitations in the methodology of the Environmental Kuznets Curve literature, economic considerations have been observed to impact upon a country's ability to introduce and implement environmental protection reforms across a range of studies employing various methodologies and analytical frameworks. The support in this varied body of literature for the proposition that economic factors influence capacity to introduce and implement environmental reforms renders economic factors an essential area for investigation in any study of the global effort to eliminated leaded vehicular fuel.

While the economic benefits of the elimination of leaded petrol are widely accepted to far outweigh any capital investment required to implement the change (UNEP Progress Achieved), for countries with limited access to capital this cost-benefit analysis has little practical effect. The UNEP's PCFV, which has played a central role in the global effort to eliminate lead since its inception in 2002, estimates that 'the lead elimination cost in ESCWA member countries is around 197 million US$' (Progress Achieved). Although the payback period is estimated at less than a year, for countries without access to capital, the USD$197 barrier must be viewed (as a matter of practicality) as a substantial hindrance to the country's efforts to eliminate lead additives from vehicular fuel.

Analysing data from 1993 and 1996, Tosun determined that '[t]he higher the per capita income of a country, the more likely the government will eliminate lead from gasoline' (2007: 5). The current study indicates that, in 2006 and 2010, the converse did not hold true. While Tosun established that higher per capita income increased the likelihood that a country would eliminate lead additives from vehicular fuel in 1993 and 1996, analysis of 2006/2010 data demonstrates that lower levels of per capita gross domestic product did not increase the likelihood that a country would have failed to eliminate lead additives from vehicular fuel. Although in both 2006 and 2010 the countries which had failed to eliminate lead additives from vehicular fuel fell to the far left of the histograms of per capita gross domestic product data, it was also true to say that the majority of countries which had eliminated leaded petrol also fell to the left of the histograms. In both 2006 and 2010, it was possible to conclude with confidence that despite a slightly lower median value in the leaded dataset, a country's per capita gross domestic product bore no relationship to whether or not lead additives had been eliminated from the country's vehicular fuel.

Of course, economic factors encapsulate a far wider range of variables than per capita gross domestic product. To further explore the relationship between economic factors and the global effort to eliminate lead petrol, the role of economic freedom was also investigated. In both 2006 and 2010, it was possible to conclude with confidence that the lower levels of economic freedom present in countries still reliant on leaded petrol was closely linked to the leaded status of countries that remained reliant on leaded fuel, suggesting that a failure to address the low levels of economic freedom present in countries still reliant on leaded petrol may be inhibiting the global effort to eliminate leaded vehicular fuel.

The disparity in findings between the effects of per capita gross domestic product (confirmed not to act as a determinant) and economic freedom (confirmed to potentially act as a determinant) on the effort to eliminate lead additives from vehicular fuel indicates that the relationship between economic factors and the elimination of leaded fuel is not explicable solely by reference to national income.

The concept of economic freedom takes into account a wider range of economic factors than national income, considering the extent of market liberalisation, government interventionism and private property rights as contributing factors to the level of economic development present in a country. Economic freedom data therefore provides a wider consideration of the economic factors operating in a country, although criticisms in the literature question the utility of privileging the liberal concepts of free trade, market liberalisation and government non-interventionism in determining the economic welfare of citizens of that country (Beghin & Potier 1997; Bhattarai & Hammig 2001; Gallagher 2004).

This study demonstrates a close correlation between economic freedom levels and the elimination of lead additives from vehicular fuel. In both 2006 and 2010, countries which continued to add lead to their vehicular fuel exhibited substantially lower levels of economic freedom as compared with their unleaded counterparts. Statistical analysis indicated that this relationship did not emerge by chance, and that the difference in levels of economic freedom between the two datasets was sufficiently substantial to have a practical effect. Although the lack of comparable time series data precluded a definitive determination of whether the relationship between economic freedom levels was causative or merely correlative, the strength of the relationship between economic freedom levels and status in relation to the elimination of leaded vehicular fuel provided considerable support for the proposition that failures to address low levels of economic freedom in countries still reliant on leaded petrol may have been acting as a barrier to the global effort to eliminate lead additives from vehicular fuel. This finding is consistent with the existing consensus within the body of literature that economic factors act as a significant determinant of a country's ability to implement environmental protection reforms.

This study also considered the effect of human development levels on the global effort to eliminate lead additives from vehicular fuel. This potential determinant emerged in the second phase of this project, and was included to further explore the impacts that socio-economic factors had on the lead status of the countries included in the study. The literature is noticeably silent on the issue of the impacts of national human development levels on environmental policymaking and implementation.

The results of this research determine that there is no relationship between a country's level of human development and its status in relation to the elimination of lead additives from its vehicular fuel. From this finding, it can be stated with confidence that the low levels of human development present in countries still reliant on leaded petrol is not acting as a barrier to the global effort to eliminate lead additives from vehicular fuel. Perhaps the absence in the literature of studies considering the effect of human development levels on national environmental reform and protection policies indicates that no connection has been made between human development levels and environmental policymaking and implementation. Were this the case, this study would then be viewed as consistent with the silence of the literature on this issue. Although this study found no relationship between lead status and human development levels, the absence of literature exploring the relationship between human development levels and environmental reform policymaking more generally suggests that this may be an area for future research.

Conflict and Peacefulness and the Elimination of Leaded Vehicular fuel

Conflict and peacefulness arose as factors for consideration in the second phase of this project, when common factors between countries which had failed to eliminate lead additives from petrol in 2006 were being extrapolated. With Afghanistan, Iraq and Myanmar exhibiting high levels of conflict over the past decade, consideration of the question of whether countries which had failed to eliminate leaded petrol exhibited higher levels of conflict than countries which had made the change, and whether conflict operates as an inhibitor of environmental change in relation to the elimination of leaded petrol, appeared a prudent research question to include in the scope of this paper.

While there is an extensive body of literature documenting the relationship between competition for natural resources and conflict (e.g. Bannon & Collier 2003) and the negative effects that conflict activities have on sustainable development (UNEP Conflicts and Disaster 2011), research into whether or not involvement in conflict inhibits a country's ability to introduce and implement environmental protection policies is extremely limited. Despite this limitation in the body of literature, the destabilising effects that conflict has on governmental systems and institutions, social cohesion, human development outcomes, population distribution, economic wellbeing and productivity outcomes is well documented (e.g. United Nations Environment Programme 2008b). Given the earlier findings in this study - that low levels of democracy, high levels of corruption and low levels of economic freedom are closely linked to the elimination of lead additives from vehicular fuel – this body of literature lends support to the proposition that the impacts of conflict on institutional factors are not conducive to efforts to eliminate lead additives from vehicular fuel.

The results of this study indicate a strong relationship between levels of peacefulness and efforts to eliminate lead additives from vehicular fuel. In 2008, it was possible to conclude that the higher levels of conflict in countries which had failed to eliminate lead was acting as a barrier to change in these countries. The results of this study indicate a strong relationship between levels of peacefulness and efforts to eliminate lead additives from vehicular fuel. In 2008, it was possible to conclude that the failure to address the higher levels of conflict in countries which had failed to eliminate lead may be acting as a barrier to change, and by 2010 the relationship between low levels of peacefulness and a propensity for continued reliance on leaded vehicular fuel was even more pronounced.

These findings are consistent with the analogous and anecdotal evidence of a connection between high levels of conflict and an institutional incapacity to introduce and implement reforms directed at environmental protection. However, in the absence of a stronger body of wider literature exploring the relationship between environmental reform and conflict levels, it is difficult to contextualise the results of this research. Consequently, further research into this area is required.

Directions for future research

The inability of this study to definitively characterise the relationships between determinants and the global effort to eliminate lead additives from vehicular fuel as causative or merely correlative is a serious limitation of this paper. A study that was able to produce comparable time series data in order to develop a definitive test of causality would have considerable value in further illuminating existing barriers to the global effort to eliminate lead additives from vehicular fuel. An analytical framework built on multiple regression analysis would aid in this endeavour, and would also enable a comparison of the relative influence of each potential determinant as a barrier to environmental reform in the area of the elimination of leaded vehicular fuel.

Further study could consider the effect of a number of potential determinants which were unable to be investigated in this study due to a lack of available data. These potential determinants include the presence and activity of environmental NGOs (see Tosun 2007), regulatory structures, technology levels (especially in relation to refining technologies and the numbers of vehicles fitted with catalytic converters – see Hestler and Spilling 2010) and cultural dimensions (see Husted 2005). Each of these factors emerged in the first phase of research of this study as potential barriers to the global effort to eliminate lead additives from vehicular fuel, but due to an inability to access appropriate datasets were excluded from the scope of this paper. Further research addressing these factors would advance our understanding of the factors constraining change in relation to the global effort to eliminate lead additives from vehicular fuel.

Conclusion

This study did not attempt to quantify the impact of identified determinants on a country's capacity to eliminate lead additives from its vehicular fuel. Rather, this study aimed to identify whether or not relationships exist between the proposed determinants of social change and a country's status in relation to the elimination of lead additives from their vehicular fuel. This study was conducted with a view to developing foundational understanding of the factors hindering the global effort to eliminate lead additives from vehicular fuel by inhibiting change in countries which continue to rely on leaded petrol.

The study indicates high levels of correlation between a country's status in relation to the elimination of lead additives from vehicular fuel and their levels of democracy, levels of corruption, levels of press freedom, levels of economic freedom and levels of peacefulness. While the absence of comparable time series data precluded the definitive determination of whether observed relationships between isolated determinants of environmental policy and the elimination of lead additives to vehicular fuel were causative in nature or simply highly correlative, it was possible to determine that these relationships had not emerged by chance, and that these relationships were of substantial practical effect. Read in light of the wider body of literature, these results provide strong support for the proposition that failures to address the higher levels of corruption and lower levels of democracy, press freedom, economic freedom and peacefulness in countries reliant on lead additives to vehicular fuel may be inhibiting the global effort to eliminate lead additives from vehicular fuel.

The absence of correlations between per capita GDP values, human development levels and a country's status in relation to the elimination of leaded vehicular fuel made it possible to state with confidence that neither per capita GDP values nor human development levels are causally related to a country's capacity to eliminate leaded petrol. Consequently, neither per capita GDP values nor human development levels can be considered barriers to the global effort to eliminate lead additives from vehicular fuel.

Directions for future research include analyses of comparable time series data, which would enable definitive determinations of causality to be made in relation to the correlations observed between various determinants of environmental policy and the global effort to eliminate lead additives from vehicular fuel. Further study could also employ multiple regression analysis methodologies in order to measure the relative impacts of each determinant on the elimination of leaded vehicular fuel.

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