Do We Need More Babies to Save the Planet?

A Study on Greenhouse Gas Emissions & Population Growth

MGT 6203 Group 64

Agenda

01 Team Introduction

02 Background

03 Data Prep & EDA

04 Methodology

05 Results

06 Conclusion

Team Introduction

Nitya Nandagopal

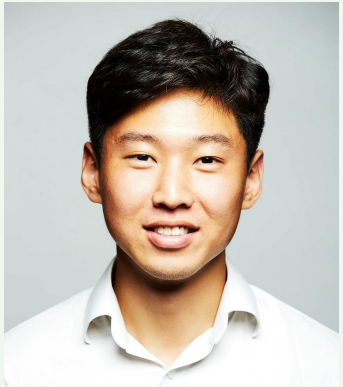
Data Scientist @ Verizon
Bachelor's in Electrical & Computer Engineering from the University of Texas at Austin.
Previous projects include forecasting equipment run rates in a cellular network and predicting budgetary needs of different business units.

Jessica Petersen

HSE Project Manager @ Cummins
Bachelor's in Chemical Engineering from Georgia Institute of Technology.
Previous projects include using a statistical approach to determine leading indicators that can predict increasing injury rates in the workplace.

Melissa Gibson

Senior Accountant @ Environmental Defense Fund
Bachelor's in Accounting from The College of New Jersey.
Previous projects include using a statistical approach to predict musician/entertainment booking prices for private events.

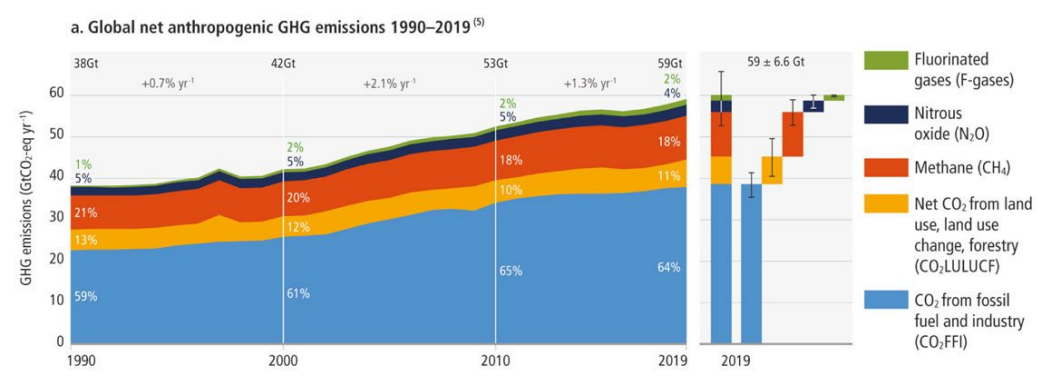


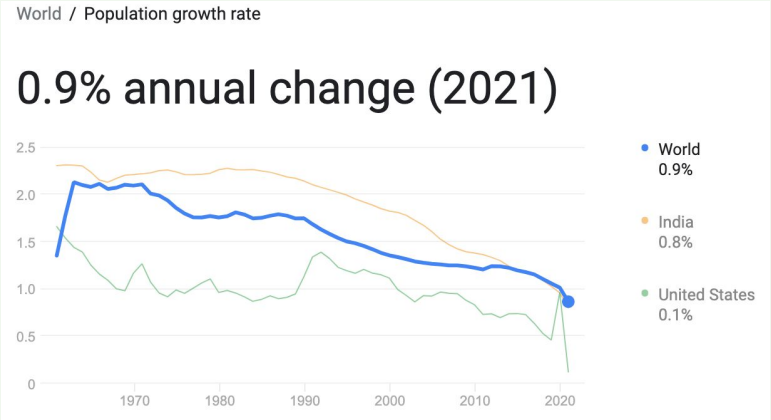
Stephen Kim

Data Scientist @ Credit Suisse
Bachelor's in Business Administration from the University of Notre Dame.
Previous projects include using a statistical approach to predict future times of payment completion by the bank's counterparty for intraday matching.

Background

- GHGs have been steadily increasing over the last century
- The world's overall population has increased, but the growth rate is slowing



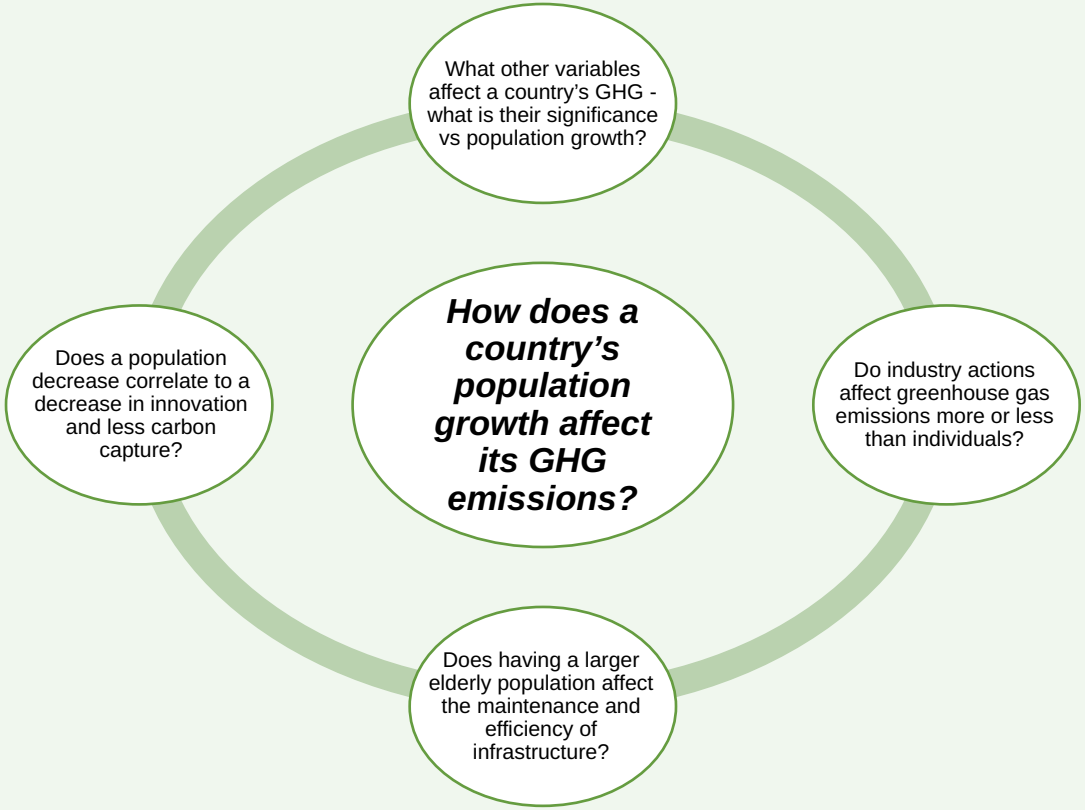


Literature Review

- Kaya Identity
  - Emissions = population x per capita GDP x energy used per unit of GDP x CO2 generated per unit of energy
- IPAT Equation
  - Environmental Impact = Population x Affluence x Technology
- Conflicting opinions among experts
- Implications
  - Environmental
  - Economical

Research Questions

Hypothesis:
Population growth is not the most contributing factor to GHG emissions



Datasets

World Population Growth Data
Source: Worldbank

Data Source	World Development Indicators						
Country Name	**Country Code**	**Indicator Name**	**Indicator Code**	**1960**	**1961**	**1962**	**1963**
Aruba	ABW	Population, total	SP.POP.TOTL	54,608.00	55,811.00	56,682.00	57,475.00
Africa Eastern and	AFE	Population, total	SP.POP.TOTL	130,692,579.00	134,169,237.00	137,835,590.00	141,630,546.00
Afghanistan	AFG	Population, total	SP.POP.TOTL	8,622,466.00	8,790,140.00	8,969,047.00	9,157,465.00
Africa Western and	AFW	Population, total	SP.POP.TOTL	97,256,290.00	99,314,028.00	101,445,032.00	103,667,517.00
Angola	AGO	Population, total	SP.POP.TOTL	5,357,195.00	5,441,333.00	5,521,400.00	5,599,827.00
Albania	ALB	Population, total	SP.POP.TOTL	1,608,800.00	1,659,800.00	1,711,319.00	1,762,621.00
Andorra	AND	Population, total	SP.POP.TOTL	9,443.00	10,216.00	11,014.00	11,839.00
Arab World	ARB	Population, total	SP.POP.TOTL	93,359,407.00	95,760,348.00	98,268,683.00	100,892,507.00
United Arab Emira	ARE	Population, total	SP.POP.TOTL	133,426.00	140,984.00	148,877.00	157,006.00
Argentina	ARG	Population, total	SP.POP.TOTL	20,349,744.00	20,680,653.00	21,020,359.00	21,364,017.00
Armenia	ARM	Population, total	SP.POP.TOTL	1,904,148.00	1,971,530.00	2,039,346.00	2,106,142.00
American Samoa	ASM	Population, total	SP.POP.TOTL	20,085.00	20,626.00	21,272.00	21,949.00
Antigua and Barbu	ATG	Population, total	SP.POP.TOTL	55,342.00	56,245.00	57,008.00	57,778.00
Australia	AUS	Population, total	SP.POP.TOTL	10,276,477.00	10,483,000.00	10,742,000.00	10,950,000.00
Austria	AUT	Population, total	SP.POP.TOTL	7,047,539.00	7,086,299.00	7,129,864.00	7,175,811.00
Azerbaijan	AZE	Population, total	SP.POP.TOTL	3,894,500.00	4,045,750.00	4,168,150.00	4,293,550.00
Burundi	BDI	Population, total	SP.POP.TOTL	2,746,628.00	2,815,972.00	2,887,398.00	2,948,133.00
Belgium	BEL	Population, total	SP.POP.TOTL	9,153,489.00	9,183,948.00	9,220,578.00	9,289,770.00
Benin	BEN	Population, total	SP.POP.TOTL	2,512,284.00	2,551,216.00	2,593,302.00	2,638,082.00
Burkina Faso	BFA	Population, total	SP.POP.TOTL	4,783,259.00	4,852,833.00	4,924,497.00	4,998,671.00
Bangladesh	BGD	Population, total	SP.POP.TOTL	50,396,429.00	51,882,769.00	53,461,661.00	55,094,115.00
Bulgaria	BGR	Population, total	SP.POP.TOTL	7,867,374.00	7,943,118.00	8,012,946.00	8,078,145.00
Bahrain	BHR	Population, total	SP.POP.TOTL	160,691.00	166,970.00	173,359.00	179,891.00
Bahamas, The	BHS	Population, total	SP.POP.TOTL	114,500.00	120,216.00	126,305.00	132,639.00
Bosnia and Herzeg	BIH	Population, total	SP.POP.TOTL	3,262,539.00	3,325,333.00	3,387,512.00	3,448,532.00
Belarus	BLR	Population, total	SP.POP.TOTL	8,198,000.00	8,271,216.00	8,351,928.00	8,437,232.00
Belize	BLZ	Population, total	SP.POP.TOTL	91,403.00	93,757.00	96,188.00	98,862.00
Bermuda	BMU	Population, total	SP.POP.TOTL	44,400.00	45,500.00	46,600.00	47,700.00
Bolivia	BOL	Population, total	SP.POP.TOTL	3,707,515.00	3,784,744.00	3,864,140.00	3,945,729.00
Brazil	BRA	Population, total	SP.POP.TOTL	73,092,515.00	75,330,008.00	77,599,218.00	79,915,555.00
Barbados	BRB	Population, total	SP.POP.TOTL	232,550.00	233,698.00	234,829.00	235,875.00

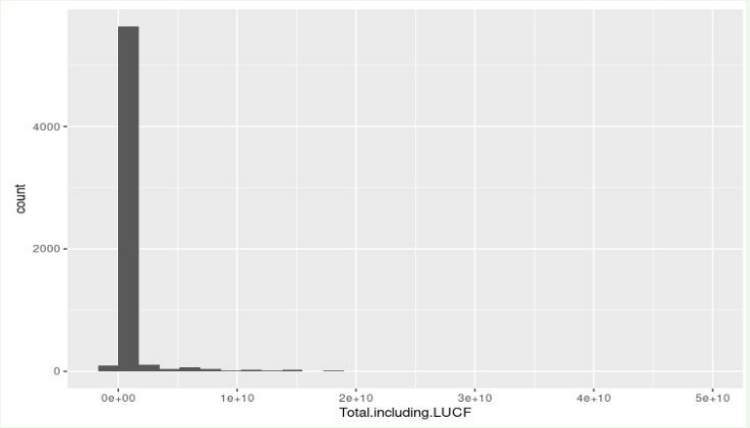
Datasets

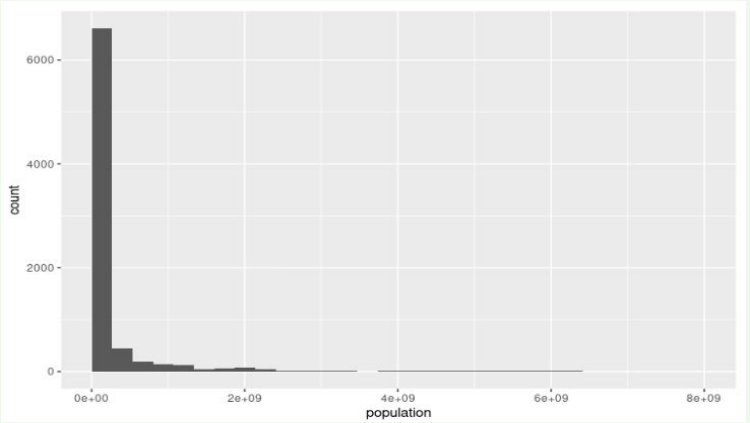
Greenhouse Gases Emissions Data
Source: Our World in Data

Entity	Code	Year	Total including LUCF
Afghanistan	AFG	1990	9579999.92
Afghanistan	AFG	1991	9810000.42
Afghanistan	AFG	1992	9029999.73
Afghanistan	AFG	1993	9109999.66
Afghanistan	AFG	1994	9149999.62
Afghanistan	AFG	1995	9579999.92
Afghanistan	AFG	1996	10609999.7
Afghanistan	AFG	1997	11579999.9
Afghanistan	AFG	1998	12399999.6
Afghanistan	AFG	1999	13279999.7
Afghanistan	AFG	2000	11500000
Afghanistan	AFG	2001	12369999.9
Afghanistan	AFG	2002	15010000.2
Afghanistan	AFG	2003	15649999.6
Afghanistan	AFG	2004	15439999.6
Afghanistan	AFG	2005	16350000.4
Afghanistan	AFG	2006	16870000.8
Afghanistan	AFG	2007	17260000.2
Afghanistan	AFG	2008	20659999.8
Afghanistan	AFG	2009	22750000
Afghanistan	AFG	2010	27239999.8
Afghanistan	AFG	2011	29170000.1
Afghanistan	AFG	2012	28549999.2
Afghanistan	AFG	2013	26770000.5
Afghanistan	AFG	2014	26520000.5
Afghanistan	AFG	2015	26840000.2
Afghanistan	AFG	2016	27049999.2
Afghanistan	AFG	2017	26680000.3
Afghanistan	AFG	2018	27840000.2
Afghanistan	AFG	2019	28790000.9
Africa		1990	2148500000
Africa		1991	2215109863
Africa		1992	2237260010
Africa		1993	2267389893
Africa		1994	2357189941
Africa		1995	2418229980
Africa		1996	2461639893
Africa		1997	2497939941
Africa		1998	2572780029
Africa		1999	2565679932

Data Cleaning

- Merged datasets on country_name and year
- Removed “rolled-up” countries
- Removed countries with frequent “NA” values
- Removed factors with frequent “NA” values





Final Cleaned Dataset

Index	Country_Code	Country_Nan	Year	age_dependa	agricultural_	fertility_rate	GDP	labor_force	life_expectai	natural_reso	energy_cons	population	GHG_with_L	deaths_air_p	GHG_withou
1	TJK	Tajikistan	1/1/90	88.6	32.07	5.34	2631768953	1372150	61.88	0.78	17274.67	5417860	17899999.6	192.5	17870000.8
2	TJK	Tajikistan	1/1/91	89.76	32.07	5.18	1352000000	1399115	61.38	0.65	15902.46	5556306	17010000.2	195.85	16969999.3
3	ARM	Armenia	1/1/91	55.7	41.1	2.65	2069870130	1645616	68.64	0	19601.42	3617631	25139999.4	134.21	25010000.2
4	GEO	Georgia	1/1/90	51.15	46.47	2.31	7753501868	2371540	68.39	0.48	24620.21	4802000	31399999.6	160.64	49759998.3
5	GEO	Georgia	1/1/92	52.86	46.47	2.13	3690328964	2443064	67.78	0.34	17979.8	4873500	14390000.3	161.89	32650001.5
6	LUX	Luxembourg	1/1/90	44.23	49.72	1.6	1.2779E+10	157920	75.44	0.04	97439.53	381850	11550000.2	40.16	12189999.6
7	LUX	Luxembourg	1/1/91	44.82	49.72	1.6	1.3834E+10	165345	75.46	0.02	103333.91	387000	12040000	38.6	12680000.3
8	LUX	Luxembourg	1/1/92	45.47	49.72	1.64	1.5519E+10	172615	75.77	0.02	102274.26	392175	11739999.8	36.65	12380000.1
9	LUX	Luxembourg	1/1/93	46.18	49.72	1.7	1.5926E+10	171764	75.71	0.02	102264.53	397475	11949999.8	35.25	12590000.2
10	LUX	Luxembourg	1/1/94	46.92	49.72	1.72	1.7702E+10	173480	76.37	0.02	97028.69	402925	11100000.4	33.56	11739999.8
11	TKM	Turkmenista	1/1/90	78.91	75.22	4.24	3188097768	1113708	63.94	77.75	40827.95	3720278	111389999	111.85	111389999
12	UKR	Ukraine	1/1/90	50.49	72.37	1.85	8.1394E+10	24262168	70.1	3.35	61924.96	51891400	776109985	99.18	824830017
13	AZE	Azerbaijan	1/1/90	63.82	53.43	2.74	8858006036	3353958	62.35	27.6	35077.66	7175200	74099998.5	146.78	75680000.3
14	AZE	Azerbaijan	1/1/91	64.3	53.43	2.87	8792365811	3405558	62.05	27.6	33210.72	7271300	71660003.7	152.9	73239997.9
15	BLR	Belarus	1/1/90	50.88	46.28	1.91	2.165E+10	4653509	70.84	0.99	44682.48	10189348	104750000	94.06	137860001
16	IRQ	Iraq	1/1/90	94.59	21.1	5.88	1.80E+11	4147362	58.44	9.86	13462.37	17658381	120150002	172.89	120279999
17	AZE	Azerbaijan	1/1/92	64.74	53.43	2.74	446305556	3545509	61.3	27.6	28049.75	7382050	80739997.9	162.53	82319999.7
18	BLR	Belarus	1/1/91	51.36	46.28	1.81	1.8E+10	4644143	70.38	1.28	44456.22	10194050	99709999.1	95.35	132809998
19	IRQ	Iraq	1/1/91	93.53	22.02	5.81	407796350	4201883	62.52	38.22	8290.51	17846378	62790000.9	169.26	62919998.2
20	BLR	Belarus	1/1/92	51.75	46.28	1.76	1.7037E+10	4659164	70.02	1.28	38484.07	10216470	86089996.3	96.47	119059998
21	IRQ	Iraq	1/1/92	92.64	21.84	5.72	553671958	4322873	66.71	38.22	12747.26	18385673	88750000	168.77	88870002.8
22	LUX	Luxembourg	1/1/95	47.59	49.72	1.7	2.0853E+10	169267	76.51	0.02	83246.71	408625	8960000.04	32.06	9600000.38
23	LUX	Luxembourg	1/1/96	48.17	49.72	1.77	2.0895E+10	171873	76.52	0.02	84460.58	414225	9039999.96	30.58	9680000.31
24	LUX	Luxembourg	1/1/97	48.61	49.72	1.71	1.9564E+10	174574	76.88	0.02	81638.43	419450	8539999.96	28.6	9180000.31
25	LUX	Luxembourg	1/1/98	48.93	49.72	1.68	2.015E+10	177043	77.02	0.02	77878.61	424700	7869999.89	26.98	8510000.23
26	LUX	Luxembourg	1/1/99	49.2	49.72	1.74	2.1899E+10	182734	77.77	0.02	81191.31	430475	8260000.23	25.12	8899999.62
27	AGO	Angola	1/1/90	94.86	36.42	7.27	1.1229E+10	4889409	41.89	28.94	1972.41	11828638	66160003.7	279.22	43150001.5
28	AGO	Angola	1/1/94	96.56	36.92	6.99	4438321017	5527396	43.42	51.69	1765.6	13462031	73160003.7	269.94	50159999.9
29	GNQ	Equatorial G	1/1/90	82.55	8.3	5.99	112119407	156528	50.86	20.97	1092.66	465549	4010000.23	306.68	170000
30	GNQ	Equatorial G	1/1/91	83.43	8.23	5.99	110906032	161560	50.97	17.03	1052.91	483142	4150000.1	299.99	319999.99
31	GNQ	Equatorial G	1/1/92	84.26	8.16	5.98	134707184	166853	51.11	20.16	1017.29	501334	5900000.1	290.99	2069999.93

Final Variables

Key Variables

Dependent Variable

GHG Emissions (with and without Land Use)

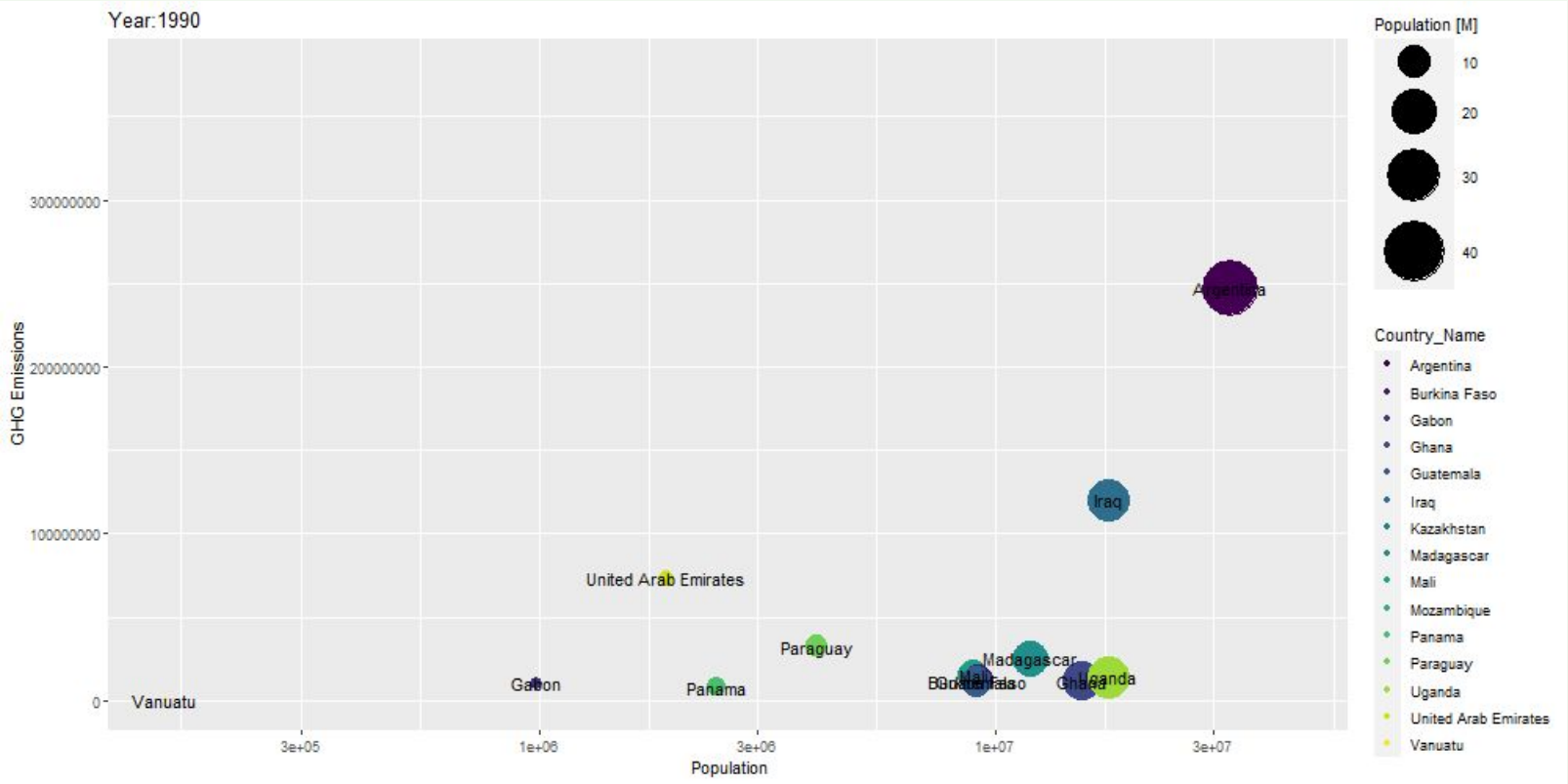
Independent Variable

Population

Additional Variables

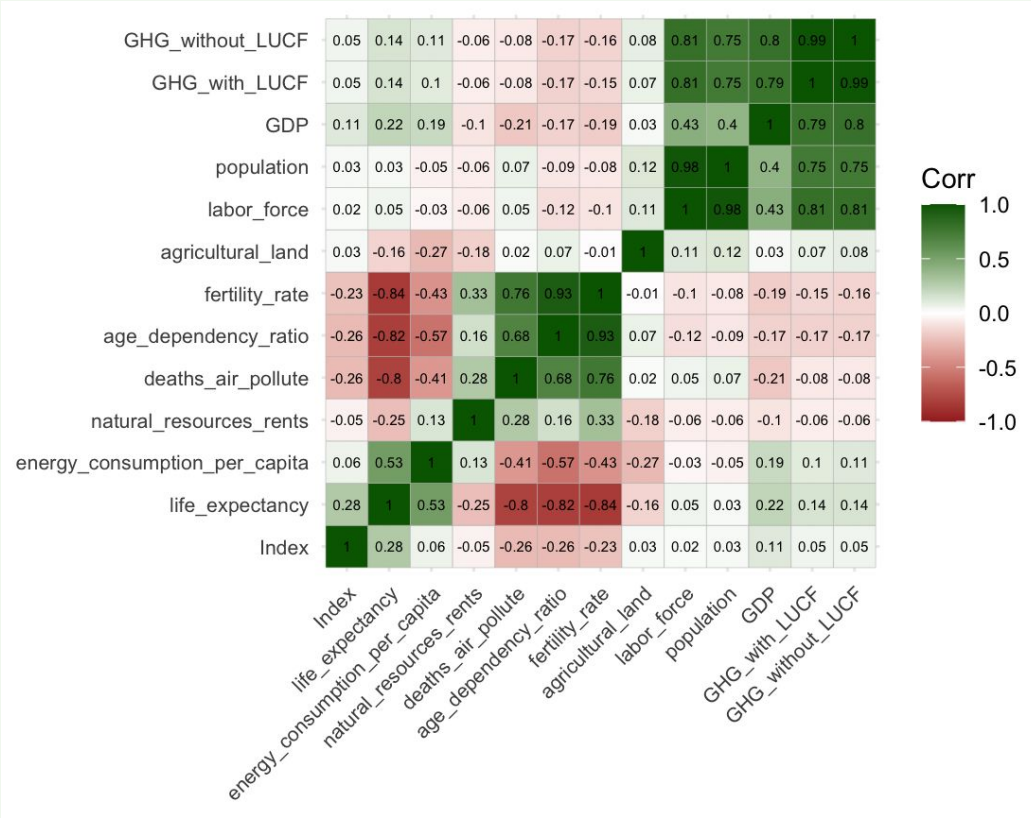
- Young to Old Person Ratio
- Birth Rate
- Percent of Agricultural Land Use
- Fertility Rate
- Life Expectancy
- GDP
- Natural Resource Rents
- Labor Force
- Energy Consumption per Capita
- Death Rate from Air Pollution

Exploratory Data Analysis

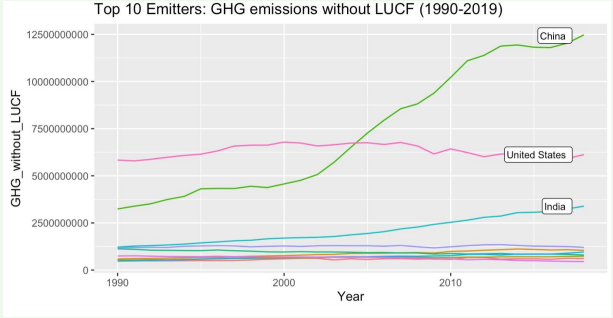


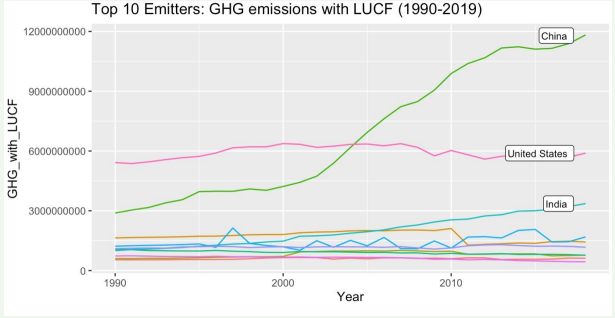
Exploratory Data Analysis

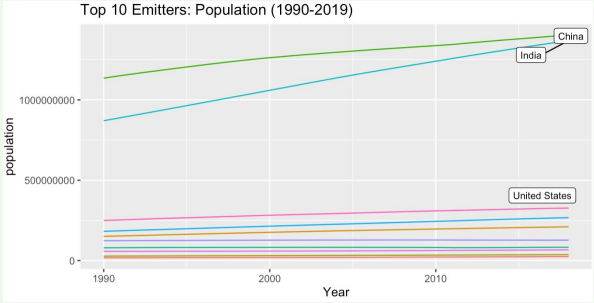
Population shows high correlation with labor_force, GDP, and GHG (with and without LUCF)



Exploratory Data Analysis







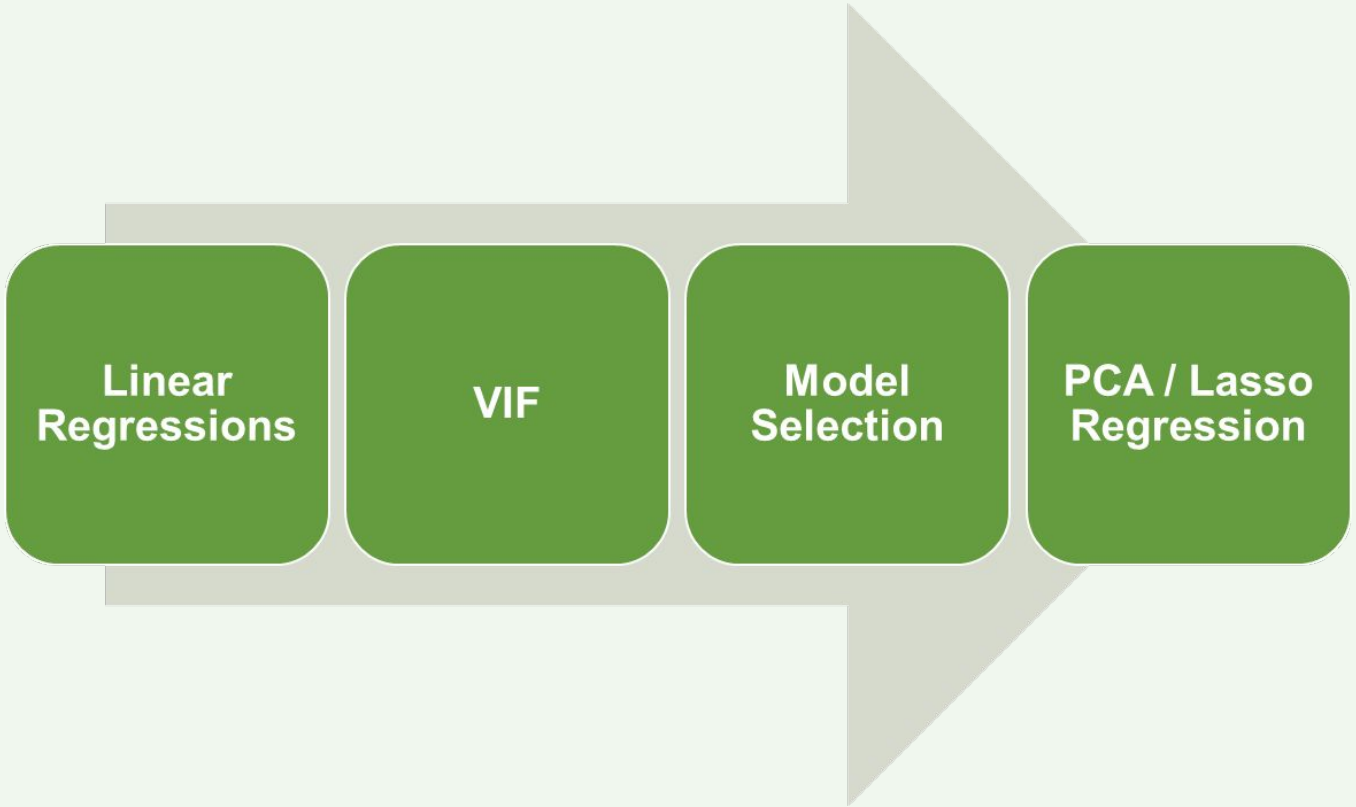
Country_Name: Australia, Brazil, Canada, China, Germany, India, Indonesia, Japan, United Kingdom, United States

Top GHG emission contributors

China
India
USA

Top population contributors

Methodology



Linear Regressions

Model 1

Dependent variable:
GHG_without_LUCF

Independent variables:
Country_Name, population, age dependency ratio, agricultural land area, fertility rate, GDP, labor force, life expectancy, natural resources rents, energy consumption per capita, and deaths from air pollution

R^2 = 0.9642891

Model 3

Dependent variable:
GHG_without_LUCF

Independent variable:
population

R^2 = 0.5662694

Model 6

Dependent variable:
Global_GHG

Independent variable:
Global_population

R^2 = 0.9751

Model 9

Removal of highly correlated variables VIF>5

Dependent variable:
GHG_without_LUCF

Independent variables:
GDP, population, agricultural_land, natural resources rents, energy consumption per capita, deaths from air pollution

R^2 = 0.8602951

For full list of models, please see the appendix

VIF Analysis

	GVIF	Df	GVIF^(1/(2*Df))
Country_Name	2.480086e+11	146	1.094012
age_dependency_ratio	2.537748e+01	1	5.037607
agricultural_land	5.624852e+01	1	7.499901
fertility_rate	4.816827e+01	1	6.940336
GDP	8.430021e+00	1	2.903450
labor_force	1.192534e+03	1	34.533080
life_expectancy	2.766264e+01	1	5.259528
natural_resources_rents	6.153199e+00	1	2.480564
energy_consumption_per_capita	2.804072e+01	1	5.295349
population	1.029402e+03	1	32.084293
deaths_air_pollute	4.895036e+01	1	6.996453

VIF for all independent variables

labor_force	age_dependency_ratio	agricultural_land
20.648364	11.278887	1.214345
fertility_rate	GDP	life_expectancy
13.479727	1.391672	5.430618
natural_resources_rents	energy_consumption_per_capita	population
1.372050	2.048128	19.853572
deaths_air_pollute		
3.314927		

VIF without Country_Name

PCA / Lasso Regression

```
12 x 1 sparse Matrix of class "dgCMatrix"
                                        s0
(Intercept)                   212525886.7
Country_Name                     113257.1
age_dependency_ratio          -47667683.2
agricultural_land              20151033.8
fertility_rate                 37948354.5
GDP                           460799518.7
labor_force                  1024781462.3
life_expectancy               -34962624.3
natural_resources_rents        15500396.3
energy_consumption_per_capita  23571768.2
population                   -519893136.0
deaths_air_pollute             -9704662.3
              RMSE          Rsquared                MAE
293805095.6283337         0.9211111 105058855.5864614
```

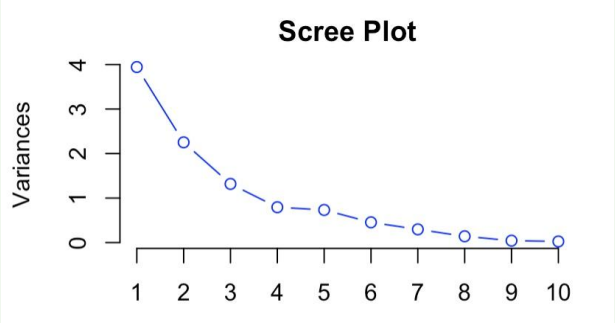
Lasso Regression

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 209754867    6698217   31.32   <2e-16 ***
PC1         112710418    3373420   33.41   <2e-16 ***
PC2         449100203    4464204  100.60   <2e-16 ***
PC3         130560265    5835524   22.37   <2e-16 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 388400000 on 3359 degrees of
freedom
Multiple R-squared:  0.7775,    Adjusted R-squared:  0.7773
F-statistic:  3912 on 3 and 3359 DF,  p-value: < 2.2e-16


              RMSE          Rsquared                MAE
 441784037.9930761         0.8219102 145069602.9210091
```

PCA Regression



PCA Scree Plot

Model Selection

Key Variables

Dependent Variable	GHG Emissions without LUCF
Independent Variable	Population

Additional Variables

- Percent of Agricultural Land Use
- GDP
- Natural Resource Rents
- Energy Consumption per Capita
- Death Rate from Air Pollution

```
Call:
lm(formula = GHG_without_LUCF ~ GDP + population + agricultural_land +
    natural_resources_rents + energy_consumption_per_capita +
    deaths_air_pollute, data = GHGdata)

Residuals:
       Min         1Q     Median         3Q        Max
-2.952e+09 -1.491e+07  2.803e+07  5.127e+07  3.983e+09

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                   219700932    4992936  44.002  < 2e-16 ***
GDP                           517322472    5691882  90.888  < 2e-16 ***
population                    450238546    5566840  80.879  < 2e-16 ***
agricultural_land              13324538    5287284   2.520   0.0118 *
natural_resources_rents        25582415    5481482   4.667 3.15e-06 ***
energy_consumption_per_capita  24674711    5947461   4.149 3.41e-05 ***
deaths_air_pollute              5075882    5989010   0.848   0.3967
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 323700000 on 4196 degrees of freedom
Multiple R-squared:  0.8625,    Adjusted R-squared:  0.8623
F-statistic:  4386 on 6 and 4196 DF,  p-value: < 2.2e-16
```

Hypothesis

Hypothesis

Population growth is not the most contributing factor to GHG emissions.

Conclusion

Hypothesis is accepted, GDP is the most contributing factor to GHG emissions.

Limitations and Challenges

Insufficient values for analysis in datasets

- Had to exclude variables that could have had big impact on models
- Had to exclude some countries without enough data

Multicollinearity between independent variables

- Linear regression assumes all variables are independent

High R^2 values in all models

- Tends to indicate overfitting

Future Improvements

With more years of data, a summarized global dataset could be used to interpret GHG emissions across the world as a whole.

As data collection improves, variables that we were forced to remove for data cleanliness issues may be able to be used.

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Data Sources:

- https://ourworldindata.org/greenhouse-gas-emissions
- https://data.worldbank.org/indicator/SP.POP.TOTL

Appendix: Model List

Model	Dependent Variable	Independent Variables	Cross-Validated R^2
Model 1	GHG_without_LUCF	Country_Name, population, age dependency ratio, agricultural land area, fertility rate, GDP, labor force, life expectancy, natural resources rents, energy consumption per capita, and deaths from air pollution	0.9642891
Model 1a (removed labor force)	GHG_without_LUCF	Country_Name, population, age dependency ratio, agricultural land area, fertility rate, GDP, life expectancy, natural resources rents, energy consumption per capita, and deaths from air pollution	0.9629279
Model 1b (removed Country)	GHG_without_LUCF	population, age dependency ratio, agricultural land area, fertility rate, GDP, labor force, life expectancy, natural resources rents, energy consumption per capita, and deaths from air pollution	0.9256678
Model 2	GHG_with_LUCF	Country_Name, population, age dependency ratio, agricultural land area, fertility rate, GDP, labor force, life expectancy, natural resources rents, energy consumption per capita, and deaths from air pollution	0.9467334

Appendix: Model List

Model	Dependent Variable	Independent Variables	Cross-Validated R^2
Model 3	GHG_without_LUCF	population	0.5662694
Model 4	GHG_without_LUCF	GDP	0.6784612
Model 5 (Removal of highly correlated variables GVIF>5)	GHG_without_LUCF	Country_Name, population, age dependency ratio, life expectancy, GDP, natural resources rents	0.9626004
Model 6	Global_GHG	Global_population	0.9751
Model 7	GHG_without_LUCF	GDP, population	0.8577862
Model 8	GHG_without_LUCF	Country_Name	0.9397507
Model 9 (Removal of highly correlated variables VIF>5)	GHG_without_LUCF	GDP, population, agricultural_land, natural resources rents, energy consumption per capita, deaths from air pollution	0.8602951