Toronto's Reaction to Fight Against Global Warming*

Lantao Cui

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Abstract

Climate change and global warming are predominant problems nowadays, in the north pole, polar ice caps are melting at a rate of almost 14% per decade. On top of that, over the past 30 years, the oldest and thickest ice in the north pole has declined by almost 95%. The majority of the Science Community believes that global warming is caused by the excessive emission of greenhouse gases such as Carbon Dioxide and Methane. Luckily, people are getting more and more aware of the global change and are willing to make changes. In this paper, we obtain a survey conducted on Toronto's residents about their perceptions of climate change and their willingness to take action on it. We aim to find out the impact of demographic factors such as personal income on people's perception of climate change.

1   Introduction

Ever since Industrial Revolution, people's life has become more and more convenient, for example, the invention of the steam engine made transportation much more easier. However, this convenience comes with great drawbacks, over the entire industrial revolution, scientist estimated that a total of 2.3 trillion tonnes of Carbon Dioxide have been released into the atmosphere, what is even worse is that those Carbon Dioxide has a life span of 300 - 1000 years, this means that those climate change can happen on the time scale of many generations' lives. The reason those green house gases cause global warming is because they will reflect the heat radiated from Earths' surface back, thus making the Earth warmer. Figure 1 shows the average land temperature on Earth in the past 100 years, Figure 2 shows the average Ocean temperature on Earth in the past 100 years, the data are obtained from Berkeley Earth Data Portal ("Data Overview," n.d.).

From the above two figures, it is very clear that the Earth's temperature is increasing rapidly after the Industrial Revolution. Based on research, Earth's temperature has risen by 0.08 Celsius per decade since 1880, and the rate of warming over the past 40 years is more than twice of that, 0.18 Celsius per decade. People might develop the illusion that because this looks like a very small increase, it will have little or no impact on Earth's environment. However, this is wrong, the total volume of the Ocean on Earth is around 1.335 billion cubic kilometers, therefore, a tremendous amount of energy is required to heat up the ocean (Dahlman and LuAnn, n.d.).

Global warming has been regarded as a high-risk problem globally because it will trigger a chain of events. For instance, the increased temperature will melt polar ice caps, then those ice water will be released into the ocean, causing the global sea level to rise. This could trigger a series of events, for example, the salinity of the ocean will decrease because of this large amount of fresh water, and the decreased salinity is deleterious for certain species such as coral reef, which is a keystone species, meaning its extinction is disastrous to the entire ecosystem. Moreover, the melting of the polar ice cap will reveal the black soil under it, those black soil will then absorb more energy from the sun, thus exacerbating global warming.

Luckily, hundreds of nations are actively trying to fight Climate Change, some are planting more trees so that the excessive Carbon Dioxide can be absorbed through Photosynthesis, and some are developing more sustainable and environment-free energy sources such as solar power. Toronto, for example, proposed an ambitious plan called TransformTO, its goal is to achieve net-zero greenhouse gas emissions. However,
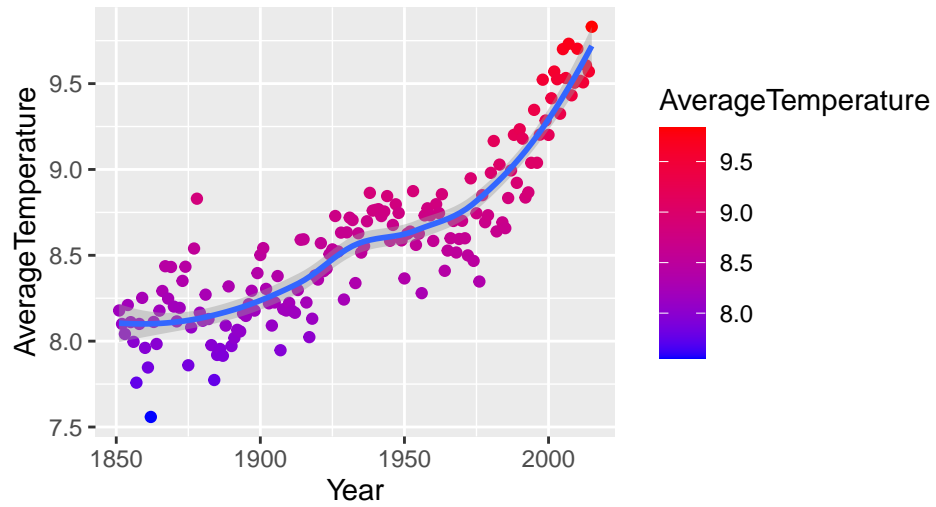
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*Code and data are available at: https://github.com/cuilantao/Toronto-s-reaction-to-fight-against-global-warming

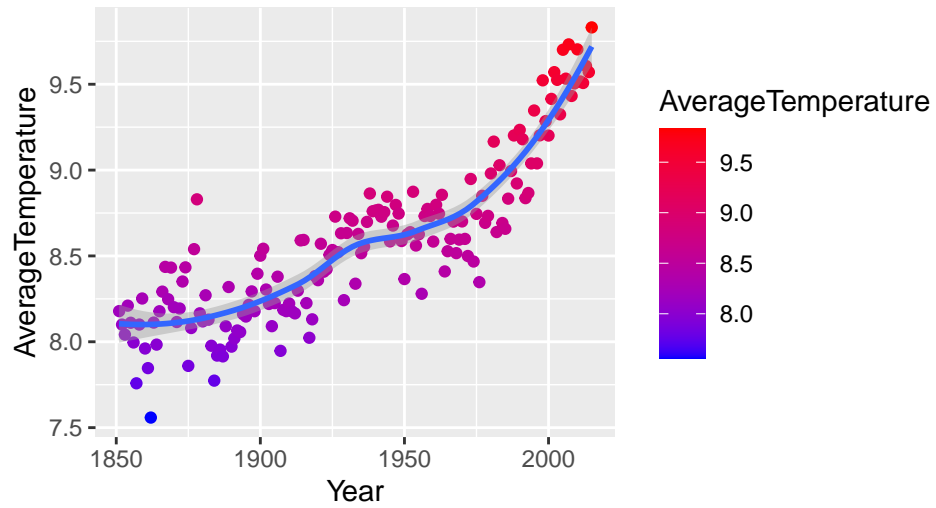Figure 1: Land Average Temperature

Figure 2: Ocean Average Temperature

everyone has a different level of education, hence it is common for people to hold different opinions about climate change. It is reasonable to believe that a university student majoring in environmental science will be more concerned about global warming than someone with high school education. To find out if there is a relationship between people's perception of climate change and their demographic factors such as income, level of education, and age, we obtained a city-wide climate perception survey dataset from the City of Toronto Data Portal (Gelfand 2020). On top of that, the report written by the City of Toronto was also helpful (n.d.).

2   Data

We started our data analysis by using R (R Core Team 2020), dplyr(Wickham et al. 2021), tidyverse(Wickham et al. 2019), here(Müller 2020). Graphs are generated using ggplot2(Wickham 2016), kableExtra(Zhu 2021), and gridExtra(Auguie 2017).

2.1   Data Source and Collection

The dataset I will be using are from the City of Toronto Data Portal, it is conducted city-wide to gather people's opinion on climate change (Gelfand 2020), the goal of this survey is to capture their perceptions about climate change and to estimate people's willingness to take actions and help the city government to establish the goal of achieving net-zero carbon dioxide emission. The survey is conducted online and a total of 404 results were received between October 11 to October 18, 2018. All survey respondents are adult residents living in the City of Toronto.

2.2   Data Overview

All respondents are from 4 geological areas: Etobicoke-York, North York, Scarborough, and Toronto and East York, Figure 3 is a bar graph showing the number of respondents from each area. Other than coming from different city areas, respondents also have different demographic backgrounds, For instance, some respondents have a household income of more than $150000 while some respondents only have a household income lower than $40000. The respondents also have a big age variety with some people being 65 years old and some only 20 years old. Below are some figures showing the distribution of the respondents based on their demographic factors. Figure 4 shows the distributions of respondents based on their age, Figure 5 shows the distribution of respondents based on their household income. Finally, Figure 6 shows the distribution of respondents based on their level of education.
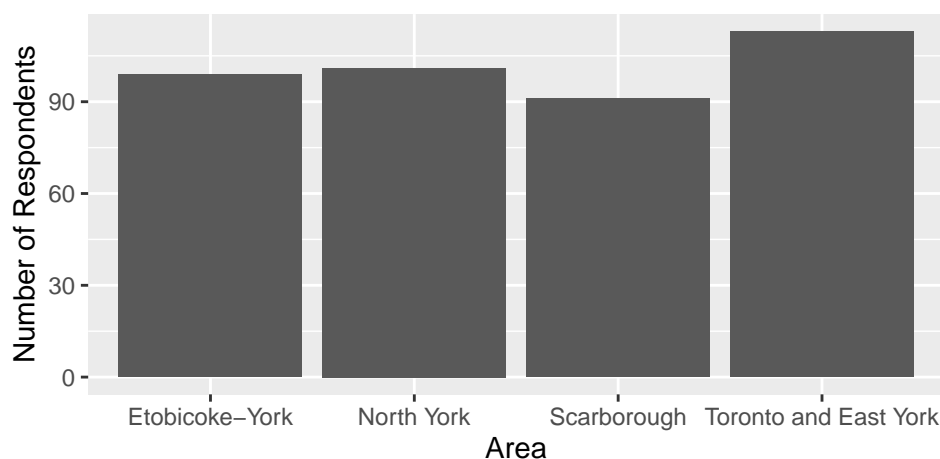

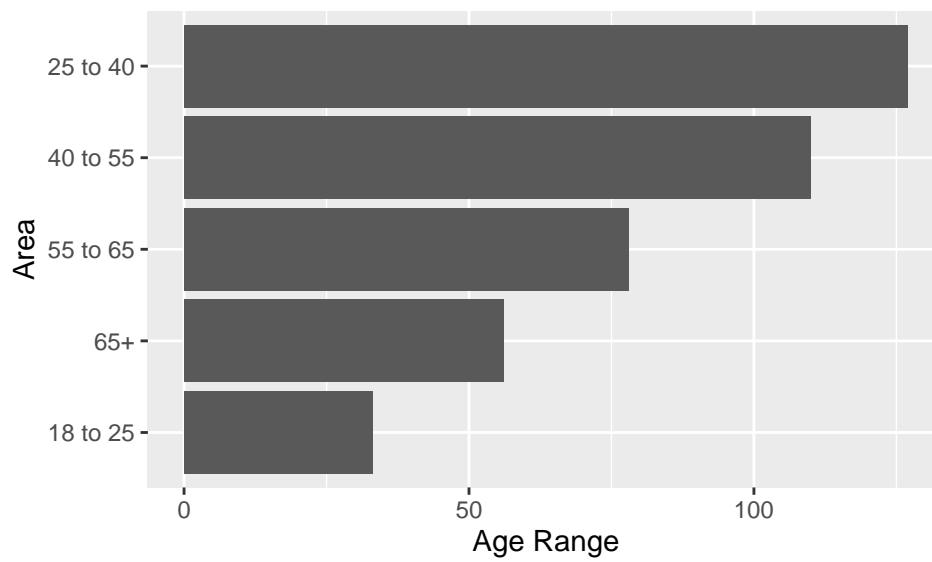
Figure 3: Number of Respondents from Each Area

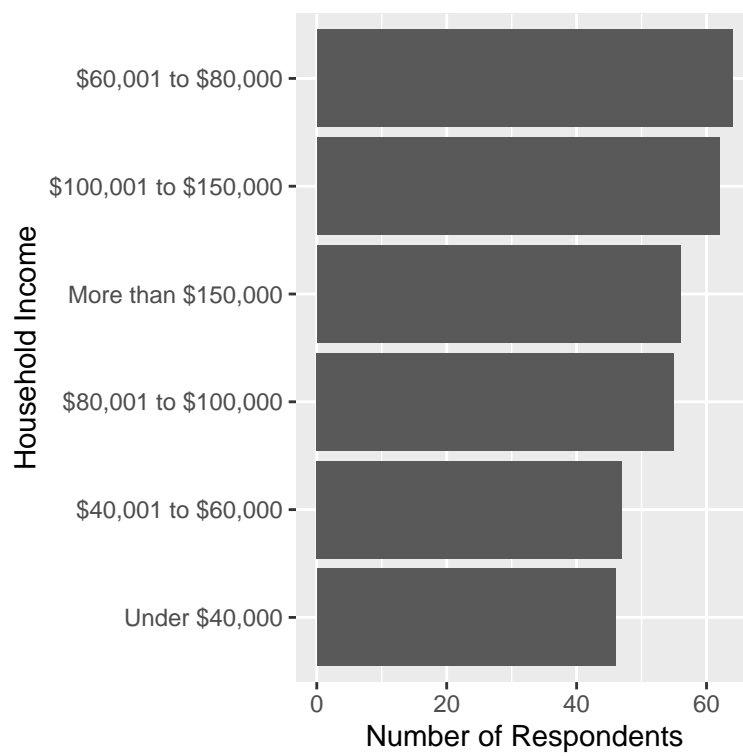Figure 4: Number of Respondents Based on Age

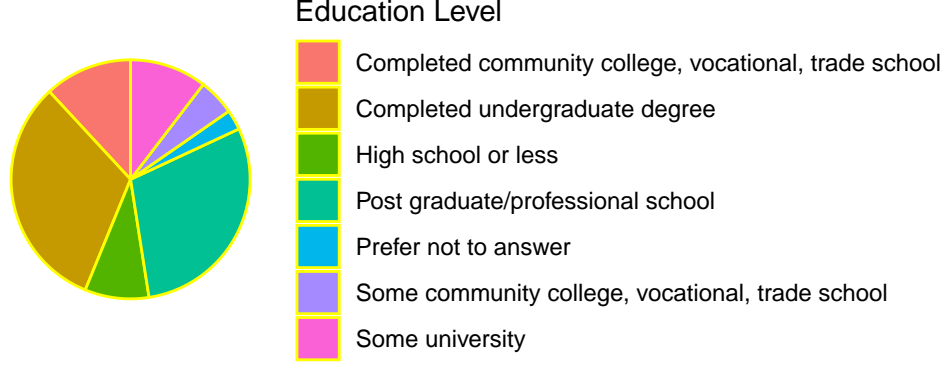Figure 5: Number of Respondents Based on Household Income

4

Education Level
- Completed community college, vocational, trade school
- Completed undergraduate degree
- High school or less
- Post graduate/professional school
- Prefer not to answer
- Some community college, vocational, trade school
- Some university

Figure 6: Number of Respondents Based on level of education

3 Models

Since our goal is to find out the impacts of demographic factors such as age, gender, income and education on one's awareness of global climate change. We will build a statistical model which takes those demographic factor as input, and output a binary variable indicating if this person will be concerned about climate change. The model will behave like the following where α_i denotes the ith demographic factor.

$$f(\alpha_0, \alpha_1, \alpha_2, \alpha_3...) = 0 \; or \; 1$$

3.1 Logistic Regresssion

Logistic regression is used when the dependent variable (target variable) is categorical, this fits perfectly here because our target variable is either *Concerned about Climate Change* or *Not Concerned about Climate Change*. Logistic regression is very similar to the traditional linear regression but it uses the regression formula inside the logistic function of $\frac{e^x}{(1+e^x)}$, so it has the following form.

$$P = \frac{e^{(\beta_0+\beta_1 X_1)}}{1 + e^{(\beta_0+\beta_1 X_1)}}$$

However, in our case, since we have several independent variables, we can instead use Multiple Logistic Regression, it has the following form

$$P = \frac{e^{(\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+...+\beta_i X_i)}}{1 + e^{(\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+...+\beta_i X_i)}}$$

3.2 Independent Variables

For our statistical model, we will try to predict whether a person will be concerned with climate change using 4 demographic factors: Age, Gender, Income, and Level of Education.

3.2.1 Age

We will investigate on whether a person's age has any effects on shaping his/her view on the global climate change.

3.2.2 Gender

Because the vast majority respondents' gender is male or female. We will neglect other gender in this paper. Because gender is used as an input to the logistic regression model, we will use 1 to represent Male and 2 to represent Female.

3.2.3 Income

The survey divides people's household income into 4 subgroups: *Under $40,000*, *$40,001 to $60,000*, *$60,001 to $80,000*, *$80,001 to $100,000*, *$100,001 to $150,000*, *More than $150,000*. We will use *$30000*, *$50000*, *$70000*, *$90000*, *$125000*, *$200000* to represent them respectively.

3.2.4 Level of Education

We will divide people's level of education into 3 groups: *High School or Less*, *Undergraduate Degree*, *Post Graduate Degree/Professional School*. We will use number 1 to 3 to represent each one of them respectively.

Above is a summary of the model and indepedent variables we will be using, more details will be presented in the Results section.

4 Results

We will first talk about each independent variable in more detail.

4.1 Relationship between People's Awareness of Climate Change and Various Demographic Factors

Our ultimate goal is to develop a statistical model which takes a person's demographic factor as input, and try to predict whether that person will be concerned about global climate change. To do this, we will take a look at different demographic factors, and determine their impacts in the model.

4.1.1 Age

Although it is a consensus that global climate change is a problem that needs to be addressed, people from different age groups might view it differently. Based on research conducted by the Pew Research Center (Tyson, Kennedy, and Funk 2021), scientists found out that Gen Z (Born after 1996) and Millennials (Born between 1981 and 1996) are usually more concerned about global climate change than the older generations. There are several reasons for this, for example, these generations generally have more access to the internet, which means they are seeing a lot of climate change content online.

We will now take a look at our survey results and determine whether age is a relevant factor. The second question in the survey is "For each of the following, how concerned are you about climate change?", the respondents can choose one from the following: "Extremely concerned, Very concerned, Not very concerned, Not at all concerned, Don't know". For simplicity, we will group *Extremely concerned* and *Very concerned* into a big category called *Concerned*, and we will group *Not very concerned* and *Not at all concerned* into a big category called *Not Concerned*, we will neglect *Don't know* answers. Table 1 is a summary table. However, the table suggests something different, we can see that people who is older than 65 years old are much more concerned about climate change than the younger generations.

4.1.2 Household income

We will also take a look at how household income affect people's opinion on global climate change. In this survey, income are separated into 6 different categories: *Under $40,000*, *$40,001 to $60,000*, *$60,001 to $80,000*, *$80,001 to $100,000*, *$100,001 to $150,000*, *More than $150,000*. Because this will be used as an input to the statistical model, we will simplify those ranges by taking its median, therefore, those range will become: *$30000*, *$50000*, *$70000*, *$90000*, *$125000*, *$200000*. (The Under 50000 and over 150000 are slightly adjusted). Table 2 is a summary table. From the table, residents that are most concerned about climate change are people with household income between 80K and 100K.

Table 1: Concern about Climate Change Based on Age Group

Age Group	Cocern Level	Percentage WRT Age Group
18 to 25	Concerned	0.75
18 to 25	Not Concerned	0.25
25 to 40	Concerned	0.81
25 to 40	Not Concerned	0.19
40 to 55	Concerned	0.75
40 to 55	Not Concerned	0.25
55 to 65	Concerned	0.81
55 to 65	Not Concerned	0.19
65+	Concerned	0.83
65+	Not Concerned	0.17

Table 2: Concern about Climate Change Based on Household income

Household Income	Cocern Level	Percentage WRT Household Income
125000	Concerned	0.82
125000	Not Concerned	0.18
2e+05	Concerned	0.73
2e+05	Not Concerned	0.27
30000	Concerned	0.87
30000	Not Concerned	0.13
50000	Concerned	0.85
50000	Not Concerned	0.15
70000	Concerned	0.76
70000	Not Concerned	0.24
90000	Concerned	0.89
90000	Not Concerned	0.11

4.1.3 Gender

We will now take a look at how people's gender affect their opinion on global climate change. The survey provides 5 options: *Woman*, *Man*, *Transgender*, *Prefer not to say*, *Not listed above*, since the vast majority respondents indicated their gender to be either *Man* or *Woman*, we will neglect the rest. For simplicity, we will use 1 to represent Male and 2 to represent Female. Table 3 is a summary table. From the results, we can see that female are usually more concerned about climate change than males.

Table 3: Concern about Climate Change Based on Gender

Gender	Cocern Level	Percentage WRT Gender
1	Concerned	0.72
1	Not Concerned	0.28
2	Concerned	0.87
2	Not Concerned	0.13

4.1.4 Level of Education

Finally, we will look at the effect of education on people's awareness of climate change. There are 6 valid responses, for simplicity, we categorize them into 3 groups: *High School or Less*, *Undergraduate Degree*, *Post*

Graduate Degree/Professional School, we will label them from 1-3 respectively. Table 4 is a summary table. From the table, clearly people with a higher level of education are usually more concerned with the climate change.

Table 4: Concern about Climate Change Based on Level of Education

Education	Cocern Level	Percentage WRT Education
1	Concerned	0.69
1	Not Concerned	0.31
2	Concerned	0.78
2	Not Concerned	0.22
3	Concerned	0.87
3	Not Concerned	0.13

4.2 Model Results

We will now fit the data, Figure 7 shows the table of model results, it is produced by model summary (Arel-Bundock 2022).

	Model 1
(Intercept)	−1.613
	(0.862)
Age	0.088
	(0.129)
Gender	1.236
	(0.332)
Education	0.593
	(0.260)
Income	−0.036
	(0.086)
Num.Obs.	325

Figure 7: Model Summary

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