NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

# BC3406 Business Analytics Consulting

## Consulting Engagement Report

## Group 7 - MacroSolutions



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# Executive Summary

## Overview

Plastic has been one of the most impressive human inventions - from the use of plastic bags, to water bottles, they've made our lives incredibly convenient, albeit at a heavy cost to the environment. It is without a doubt that anybody on the street these days will know about the pollution that plastic has on our environment. However, little to no awareness has been raised about the **effect of plastic on our health**.

Single-use plastics that are discarded by consumers after a single use, pose significant environmental problems as these discarded plastics eventually reach landfills, oceans and other waterways. These plastics then **degrade to form micro or nano-plastics** that have led to serious concerns on the toxic risks posed to human health - arising from their toxicity, associated chemicals, and ability to absorb pathogens and contaminants from the environment (Heather A, 2021).

## Problem Formation

Studies demonstrate a **potential link between microplastics and breast cancer**. Certain plastic components such as bisphenols and additives, heavy metals such as cadmium and PFAS, all leach from microplastics. Such EDCs can act as oestrogen mimics and so may increase breast cancer risk. Also, the presence of microplastics can increase the accumulation of pollutants in aquatic species, for example, PCBs in rabbitfish, PAHs in mussels etc. Exposure to such cancer-causing compounds, through consumption of seafood, may also increase breast cancer risk (Rodgers et al., 2017).

In the context of Singapore, breast cancer is the most commonly occurring cancer amongst the women here. Each year, over 2000 women are diagnosed with breast cancer, and over 400 die from the disease. There has been more than a 3x increase in the incidence rate of breast cancer amongst women in Singapore. In particular, the figure has risen from 23.8 in 1980 to 65.3 in 2015 (Health Factsheet, 2012).

Following this increasing trend in microplastics pollution and breast cancer incidence in Singapore, our team has decided to work on uncovering this correlation. In particular, we are interested in finding out the **impact of microplastics on breast cancer incidence**. In order to reinforce our results gained from this investigation, we will also be investigating the impact of breast cancer incidence on the **healthcare expenditure** in Singapore.

## Key Insights

In order to approach this problem in a holistic manner, we must first gather other factors that may potentially affect breast cancer incidence. In particular, our team has gathered data from research articles and journals to identify 6 other predictors, such as median age of woman at

child birth, smoking, alcohol and obesity in females to obtain a ‘clear picture’ on how microplastic pollution affects breast cancer rates in females.

The data we have gathered are time-series data that give us the predictors’ data for each year. With this time-series data, it is also important that we conduct a time interval difference for each variable. This is because there will be predictors that do not have an instant impact on the breast cancer incidence rate. In particular, research has proven that predictors such as alcohol consumption and cigarette consumption will cause a higher risk of breast cancer. However, the effect is not immediate and thus we must conduct further investigation to obtain the time lag for each relevant predictor.

After performing all the necessary data preparation, our team has conducted an extensive stepwise regression model on our data and here are the key insights obtained from the model:

Given a **1% Increase in Microplastics Emission**, the Singapore Government can expect an increase of **222 Breast Cancer Incidence** in Singapore, and subsequently cause an increase in Healthcare Expenditure by **$59 million.**

## Key Recommendations

Our recommendations would be a three pronged approach. We would like the government to **tax producers, incentivize merchants and educate consumers.**

[Producers] Single Use Plastic Tax/Policy Reform

This recommendation would be to nip the problem at its bud. With this tax, which would be similar to the carbon tax that Singapore has implemented in 2019, there would be an increased cost to producing plastic products. This encourages producers to research and develop new ways and materials to produce their products with.

[Merchants] GST Suspension/Reduction for Fish Imports in Selected Areas

In order to encourage merchants to import seafood from areas with less microplastics, which would directly decrease the amount of microplastics that Singaporeans are exposed to, we would like to recommend the suspension or reduction of import tax imposed on these areas.

[Merchants] Market-Based Policy Instrument

We would like to provide an extrinsic motivator to consumers through discounts by merchants, and also encourage more zero-waste merchants through additional rebates by the government.

[Consumers] Using Science and Education Material to Inform the Public

The most effective recommendation would be to educate the consumers on the negative impacts of microplastics. Powered with the knowledge, consumers would refrain from habits that would allow microplastics to enter their bodies, as well as make microplastic-conscious decisions that would signal merchants and producers on the shift in consumer preferences, and hence reduce the demand for microplastic emitting products.

# Appendix

## Introduction

14 million tonnes of microplastics (MP) have been found on the ocean floor (Khare, 2020), and they have been found in seabed dwelling sharks (Galloway, 2020). There has already been evidence that MPs are found in human faeces (Yan et al., 2021), which proved that humans did ingest MPs. It was only a matter of time before microplastics would be found in human blood, and it was, and the finding was published on 24 March 2022 (Leslie et al., 2022).

Concerns have risen regarding this, such as whether the microplastics will cross the blood-brain barrier (as it has in mice, (Kwon et al., 2022)), or whether it will affect babies (microplastics can pass through placentas (Ragusa et al., 2021)), and what other ways may microplastics affect human health? In our report, we will discuss the impact of microplastics on breast cancer.

## Problem Statement

**Target Audience: Singapore Government**

Breast Cancer is the most commonly diagnosed cancer among women in Singapore. It is said that breast cancer accounts for up to 17% of cancer-related deaths in women, and 1 out of 16 women in Singapore is likely to be diagnosed with it. (*Health Factsheet*, 2012)

In conjunction with the increasing health expenditure specifically on cancer drugs and with research articles depicting the effects of microplastics on causing breast cancer (Rodgers et al., 2017), our team has decided to suit up and venture out to find the impact of microplastics on breast cancer incidence worldwide.

In order to bring this problem to the Singapore context, we have decided to also measure the impact of breast cancer incidence on our government's health expenditure costs. This form of approach will allow us to have a birds eye view of the issue on microplastics, but at the same time also allow us to draw conclusions and impact for our specific target audience.

# Background Information

## Sources of Microplastic Pollution (MPP)

Microplastics come in the environment from two main types of sources - **Primary** and **Secondary Microplastics.**
Primary microplastics are released directly into the air and the major sources are - laundering of synthetic clothes (35% of primary microplastics), abrasion of tyres through driving (28%). These microplastics are estimated to represent between 15-31% of microplastics in the ocean.

Secondary microplastics, on the other hand, originate from degradation of larger plastic objects, such as plastic bags, bottles or fishing nets. These particles account for 69-81% of microplastics found in the oceans.

As a result, microplastics are found in growing quantities in the ocean. According to the UN, there are as many as **51 trillion microplastic particles** in the world ocean, **500 times** more than stars in our galaxy. These particles found in the ocean can be ingested by marine animals, which can end up in humans through the food chain. (Microplastics: Sources, Effects and Solutions | News, 2018)

## Effects of Microplastics on Human Health

Humans may ingest microplastics directly via consumption of microplastic contaminated water, soil or salt, or indirectly via trophy transfer such as consumption of microplastic contaminated seafood.

The greatest exposure might be through **seafood consumption**, serving as a major protein source and as the sea happens to be a hotspot for plastic debris pollution. Research has shown that ingested microplastics can be retained in the cells or tissues for extended periods where they may cause abrasion and damage to internal tissues (*How Harmful Are Microplastics? — Science Learning Hub*, 2019).

Ingested microplastics cause serious concerns on the toxic risks posed to human health - arising from the microparticles' toxicity, associated chemicals, and ability to absorb pathogens and contaminants from the environment (Heather, 2021). These microplastics can carry a range of contaminants such as trace metals and potentially harmful organic chemicals, which increases the potential for toxic effects. According to a study, as certain microplastic particles enter the human body, their rate of elimination from the body is slower than rate of absorption into the blood. These microplastic particles, carrying carcinogenic or mutagenic chemicals, are toxic to humans and can potentially cause **cancer** and/or **DNA damage** (Verla, 2019).

## How Microplastics possibly cause Breast Cancer

Microplastics can carry a range of contaminants such as trace metals and potentially harmful organic chemicals, which increase the potential for toxic effects.

Certain plastic components such as bisphenols and additives, heavy metals such as cadmium and PFAS, all leach from microplastics. These chemicals can act as **endocrine-disrupting chemicals** (EDCs). Such EDCs can act as oestrogen mimics and so may increase breast cancer risk (Rodgers et al., 2017). Also, the presence of microplastics can increase the accumulation of pollutants in aquatic species. Exposure to such cancer-causing compounds, through consumption of seafood, may also increase breast cancer risk.


*Figure 1 - Biological effects of microplastics*

## Breast Cancer Trend in Singapore

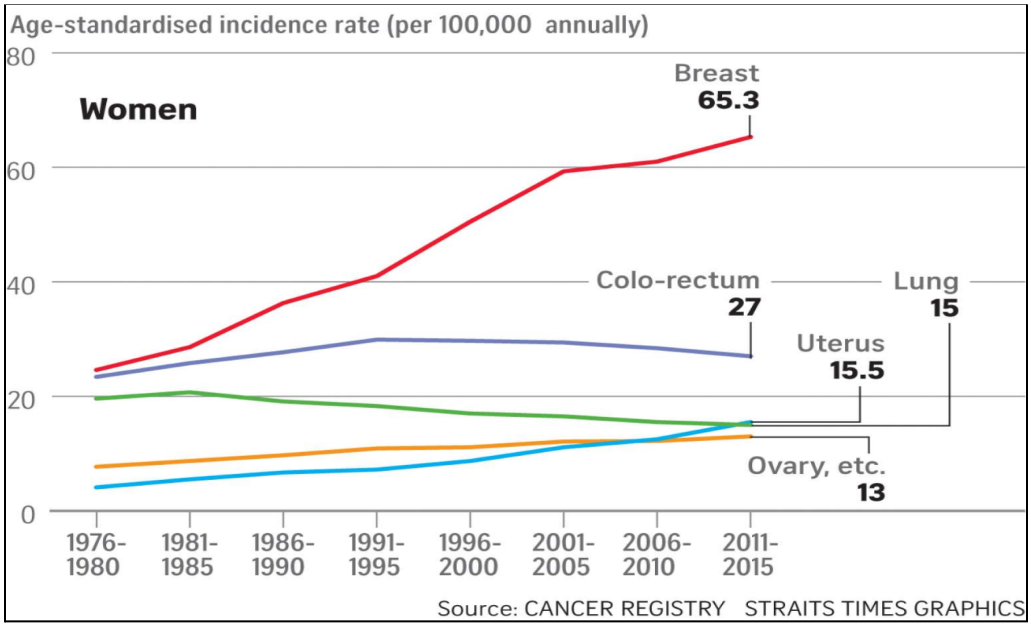



*Figure 2 - Historic Cancer Incidence Rate*

It is said that breast cancer accounted for around 17% of cancer-related deaths in women and almost 1 out of 16 women in Singapore is likely to be affected by breast cancer.

As seen in Figure 2, there is more than a 3x increase in the incidence rate for Breast Cancer in Singapore. In particular, the figure has risen from 23.8 in 1980 to 65.3 in 2015 (Health Factsheet, 2012).

## Cancer Expenditure in Singapore

With the increasing number of people getting cancer, it is inevitable that the number of people making Medishield claims for outpatient cancer drugs increased. Between 2017 and 2021, the number of claims increased by 30%, from 22,500 to 29,100. In total, Medishield Life paid out $168 million in claims for drugs in 2020 which is a 50% increase from what was spent in 2017. Rising cost of drugs are also one of the main concerns as traditional cancer drugs usually cost around a few hundred dollars a month, however, with the advancement of cancer treatment drugs which activate the body's immune system to fight the disease can cost higher than $5,000. In 2019 alone, Singapore spent a total of $375 million on drugs, which account for ⅓ of the nation's total drug spending and it is slated to increase with the advancement of such treatment. The compound annual growth rate for Singapore spending on cancer drugs is at 20% between 2017 and 2021 as compared to other non-cancer drugs that are experiencing 6% growth rate.If this trend were to continue, Singapore is projected to spent $2.7 billion on cancer drug alone in 2030, in which it is a 7 folds increase of what we are spending in 2018. (*Why Singapore Spends so Much on Cancer Treatment and How Changes to MediShield Life Hope to Address This*, 2021)

## Other Possible Predictors of Breast Cancer

Studies and research have found out that the risk for breast cancer can be due to a combination of factors. The main factors that influence risk include being a woman and ageing. Most of the breast cancer cases are found in women who are 40 years old or older and it is the same in Singapore context (*Breast Cancer – Causes, Symptoms & Treatment*, 2021). Hence, in order to prevent a simple linear regression model for our analysis, we decided to add other breast cancer causing risk factors into the equation. The table below are the list of other factors:

| No | Factors of Breast Cancer | Supporting References | Controllable risk factor |
|---|---|---|---|
| 1 | *Age* | Breast cancer incidence increases with age, with the vast majority of women diagnosed after the age of 40 years and this can be further reinforced by Figure 2. Nevertheless, approximately 7% of women diagnosed with breast cancer between 2000 and 2005 were below the age of 40 (*Breast Cancer*, n.d.) | No |
| 2 | *BMI* | Research has shown by using dose-response meta analysis of prospective cohort studies, every 5kg/$m^2$ increase in BMI corresponds to a 2% increase in breast cancer risk in women. (*Association Between Body Mass Index and Breast Cancer Risk: Evidence Based on a Dose–response Meta-Analysis*, 2018) | Yes |
| 3 | *Mean Age of Woman at First Child Birth* | A first pregnancy is linked to an increased short-term risk of breast cancer, but a decreased long-term risk of breast cancer.The impact of such risk depends on the age of the woman at the time of her first pregnancy. Below is the list of summary that was mentioned in the research report.<br>+ Breast Cancer risk increases for **~10 years** after a first birth. Subsequently, women who give Birth tend to have a lower risk of breast cancer than women who never give birth.<br>+ Women who give birth to the first child at a later age have a higher risk of breast cancer than those that give birth to the first child at a younger age.<br>+ Women over 35 years of age + Giving Birth to their first child: Will have a small increase in risk of developing breast cancer .<br><br>(*Breast Cancer Risk: Age at First Childbirth*, n.d.) | Yes |

| | | | |
|---|---|---|---|
| 4 | *Alcohol Consumption* | Alcohol consumption is one of the major modifiable risk factors for breast cancer. An individual that consumes a moderate amount of alcohol has been linked to an approximately 30-50% increase risk in breast cancer.<br><br>Ethanol is the type of alcohol found in most or all alcoholic drinks. Most research and studies have suggested that it is ethanol that increases the risk and not the other ingredients.<br><br>How does alcohol increase breast cancer risk:<br>+ Damage the body tissue - Cells that are damaged by alcohol may try to repair themselves which will result in a change in DNA that can potentially be a step toward cancer. Likewise, alcohol can be converted into acetaldehyde which is a chemical that can damage the DNA inside cells, where experiment has been conducted in lab animals and is found to have caused cancer.<br>+ Effects on estrogen and other hormones - Alcohol raises the level of estrogen which is a hormone that is responsible for the growth and development of breast tissue, which is mostly associated with increased risk of breast cancer in women<br>+ Effect on body weight - Excessive consumption of alcohol will add extra calories to the diet, which will contribute to weight gain (have a relative relation with BMI).<br><br>(Terry, n.d.) | Yes |
| 5 | *Cigarette Consumption* | Cigarette Smoke contains toxins, where there are plausible biological reasons why smoking could affect breast cancer risk. It contains more than 7000 different chemicals and at least 250 of these are found to be harmful to the body. These harmful chemicals can cause mutation to the DNA, potentially leading to cancer.<br><br>In 2014, a research conducted by the Surgeon General found sufficient evidence of potential factors in which smoking may cause breast cancer, further reinforcing the link between smoking and breast cancer. Especially women who started smoking during adolescence, smoked at least two packs a day, or smoked prior to their first full-term pregnancy. Smoking possesses significant health problems for an | Yes |

| | | | |
|---|---|---|---|
| | | individual and is one of the few modifiable risk factors for breast cancer development.<br><br>(Tiersten, 2021) | |
| 6 | *Reproductive Life Span* | Reproductive Life Span is a combination of two factors, age of menarche and age of menopause. Earlier age of menarche can change adipose patterns, which appear to be related to breast cancer (Stoll, 1998). Later age of menopause increases the risk of various cancers, including breast cancer (Appiah et al., 2021). With a longer reproductive life span, women are exposed to hormones for a longer period of time, and hence increasing their risk of breast cancer (Centers for Disease Control and Prevention, 2021). | No |

These 6 factors are chosen as a result of multiple research papers and studies suggesting the strong link between these 6 cancer causing risk factors and breast cancer. Likewise, we also observe that there is a possibility of some of these factors inducing the effects on the other factors such as BMI and alcohol consumption. Hence, our team has proposed the formulation of such an equation:

*Breast Cancer Rate ~ Microplastics Emission + Average Female Age + Average Female BMI + Mean Age of woman at First Birth + Alcohol Consumption + Cigarette Consumption*

## Time Lag of Predictor Variables

The time lag is the particular time period (in years) after which the predictor variable will start to increase the risk of breast cancer among females. Particular predictor variables in the regression model require time lag as it will take particular time for certain variables to exert their influence on breast cancer.

Independent variables such as **Alcohol Consumption**, **Cigarette Consumption** and **BMI** require time lag as research shows that these factors influence the risk of breast cancer after a particular time period and only after that into account, the effect of such variables on breast cancer can be assessed accurately.

Other variables such as Average Median Age (in Females) and Mean Age of Women at Child Birth do not require to take time lag into account as age is definite and requires to be current to accurately assess the breast cancer risk.

**Alcohol Consumption:** Research shows that after a median time period of **8.6 years**, alcohol consumption is likely to have an adverse effect on breast cancer (NCBI. April 3, 2022)

**Cigarette Consumption:** Research shows that after a median time period of **15 years**, smoking is likely to have an adverse effect on breast cancer (Nordqvist, C., 2019)

**BMI:** Research shows that after a median time period of **9.3 years**, women with higher BMI (>30) classified as obese, and lower BMI (<18.5) classified as underweight are likely to have an adverse effect on breast cancer. (The Premenopausal Breast Cancer Collaborative Group., 2018, November 8)

# Data and metrics

## Primary Model

This model will be used to analyse the impact of various factors on breast cancer rate.
The datasets that we have gathered for usage in our analysis are all in terms of World values. The reason for extracting data from all over the World is because we were unable to obtain such specific data from Singapore, especially given the short history of the nation. This section will explain the data we have used for our model, where we have sourced them from.

### Dependent Variable

1. **Breast Cancer Rate**
   The data source represents the yearly incidence of breast cancer in the world, in raw numbers. The data is grouped yearly by countries, and in order to prepare it for the model, we grouped all the countries together in order to form 1 data point per year. This data is further divided by the number of females in the world per year, to get the breast cancer rate of females per year.
   Source: Cancer Over Time

### Independent Variable

1. **Microplastics Emissions (Tonnes)**
   The data source represents the yearly emissions of microplastic in the world, in tonnes. The data was originally given in cumulative numbers, but is prepared into yearly numbers for the model.
   Source: Microplastics in the surface ocean, 1950 to 2050 (ourworldindata.org)
2. **Median Female BMI**
   The data source represents the yearly mean female BMI in the world, that is grouped by countries. We decided to use the yearly median female BMI instead of mean.
   Source: Mean body mass index (BMI) in women, 2016 (ourworldindata.org)
3. **Alcohol Intake (Litres per adult per year)**
   This data represents the yearly level of alcohol consumption, in litres. The data was originally grouped yearly by countries and the type of alcohol. We decided to group all the countries together, and only took into account the volume of alcohol consumed.
   Source: Levels of Consumption (who.int)
4. **Cigarettes Consumption (Cigarettes per adult per year)**
   The data source represents the yearly number of cigarettes bought by an adult per day. The data was originally grouped yearly by countries. We decided to group all countries together, and multiplied it by 365 to get the number of cigarettes bought by an adult each year.
   Source: Sales of cigarettes per adult per day, 1970 to 2015 (ourworldindata.org)
5. **Median Age (Years)**

This data represents the world median age per year.
Source: Median age, 1950 to 2020 (ourworldindata.org)

6. **Mean Age of Women at First Child Birth (Years)**
   This data represents the yearly mean age at which women had their first child. The data was originally grouped yearly by countries. We decided to group all the countries together and take the world average.
   Source: Age of mothers at childbirth and age-specific fertility
7. **Mean Reproductive Lifespan (Years)**
   This data represents the yearly mean reproductive life span of women. The reproductive lifespan of a woman refers to the number of years between the age of menarche (first menstrual cycle) and menopause.
   Source: Characteristic of US Women who reported having natural menopause (jamanetwork.com)

## Secondary Model

In this model, we will be analysing the impact of an increase in Breast Cancer Incidence on the Singapore Government. In particular, we will be diving into how much Healthcare expenditure by the government is expected to change, given an increase in Breast Cancer Incidence.

### Dependent Variable

1. Healthcare Expenditure in Singapore (% of GDP or $m)
   This data represents the historical yearly Healthcare Expenditure in Singapore, in terms of % of Singapore's GDP that year.
   Source: Current health expenditure (% of GDP) - Singapore | Data (worldbank.org)

### Independent Variable

1. Breast Cancer Incidence in Singapore (Total numbers per 100 000)
   This data represents the yearly Breast Cancer Incidence number in Singapore, per 100 000 population.
   Source: Cancer Registry Annual Report - Refer to Table 3.1(b)

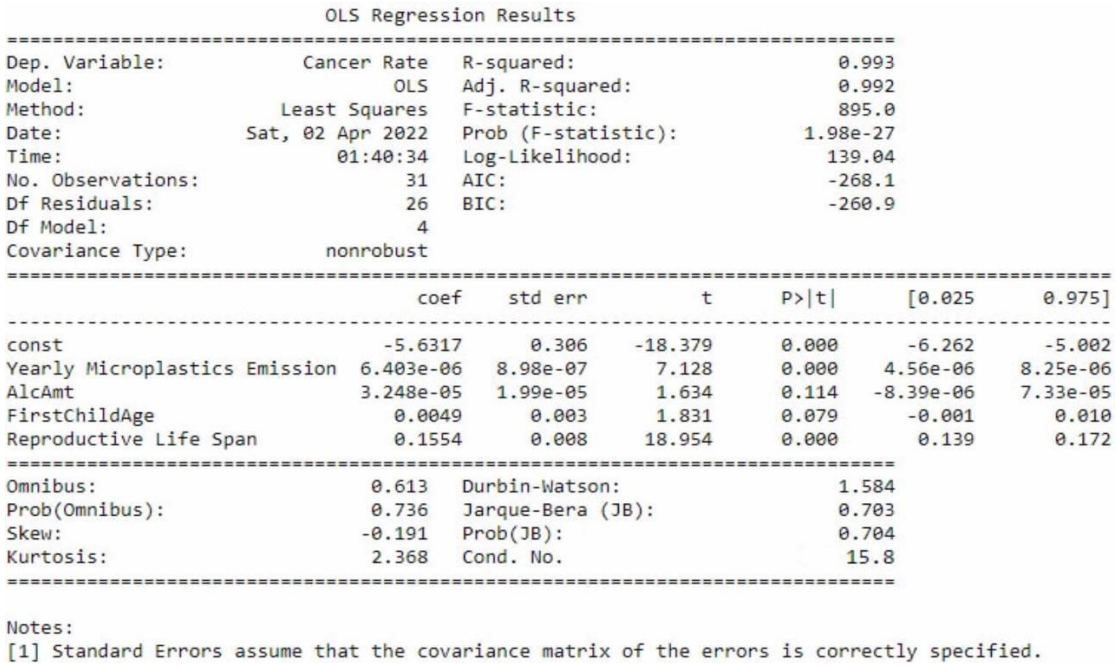
# Analytics

## Primary Model

Our initial model had 6 independent variables. However, not all the independent variables were significant and some of them had displayed multicollinearity. As a result, we decided to use stepwise regression and dropped the variables that were the most insignificant until we got a suitable model with acceptable correlation between the independent variables.

| Variable Name | Description |
|---|---|
| Yearly Microplastics Emission | Microplastics Emissions (Tonnes) |
| AlcAmt | Alcohol Intake (Litres per adult per year) |
| FirstChildAge | Mean Age of Women at First Child Birth (Years) |
| Reproductive Life Span | Mean Reproductive Lifespan (Years) |

*Breast Cancer Rate* ~ Yearly Microplastics Emission + *AlcAmt* + *FirstChildAge* + *Reproductive Life Span*



OLS Regression Results

| | | | |
|---|---|---|---|
| Dep. Variable: | Cancer Rate | R-squared: | 0.993 |
| Model: | OLS | Adj. R-squared: | 0.992 |
| Method: | Least Squares | F-statistic: | 895.0 |
| Date: | Sat, 02 Apr 2022 | Prob (F-statistic): | 1.98e-27 |
| Time: | 01:40:34 | Log-Likelihood: | 139.04 |
| No. Observations: | 31 | AIC: | -268.1 |
| Df Residuals: | 26 | BIC: | -260.9 |
| Df Model: | 4 | | |
| Covariance Type: | nonrobust | | |

| | coef | std err | t | P>\|t\| | [0.025 | 0.975] |
|---|---|---|---|---|---|---|
| const | -5.6317 | 0.306 | -18.379 | 0.000 | -6.262 | -5.002 |
| Yearly Microplastics Emission | 6.403e-06 | 8.98e-07 | 7.128 | 0.000 | 4.56e-06 | 8.25e-06 |
| AlcAmt | 3.248e-05 | 1.99e-05 | 1.634 | 0.114 | -8.39e-06 | 7.33e-05 |
| FirstChildAge | 0.0049 | 0.003 | 1.831 | 0.079 | -0.001 | 0.010 |
| Reproductive Life Span | 0.1554 | 0.008 | 18.954 | 0.000 | 0.139 | 0.172 |

| | | | |
|---|---|---|---|
| Omnibus: | 0.613 | Durbin-Watson: | 1.584 |
| Prob(Omnibus): | 0.736 | Jarque-Bera (JB): | 0.703 |
| Skew: | -0.191 | Prob(JB): | 0.704 |
| Kurtosis: | 2.368 | Cond. No. | 15.8 |

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

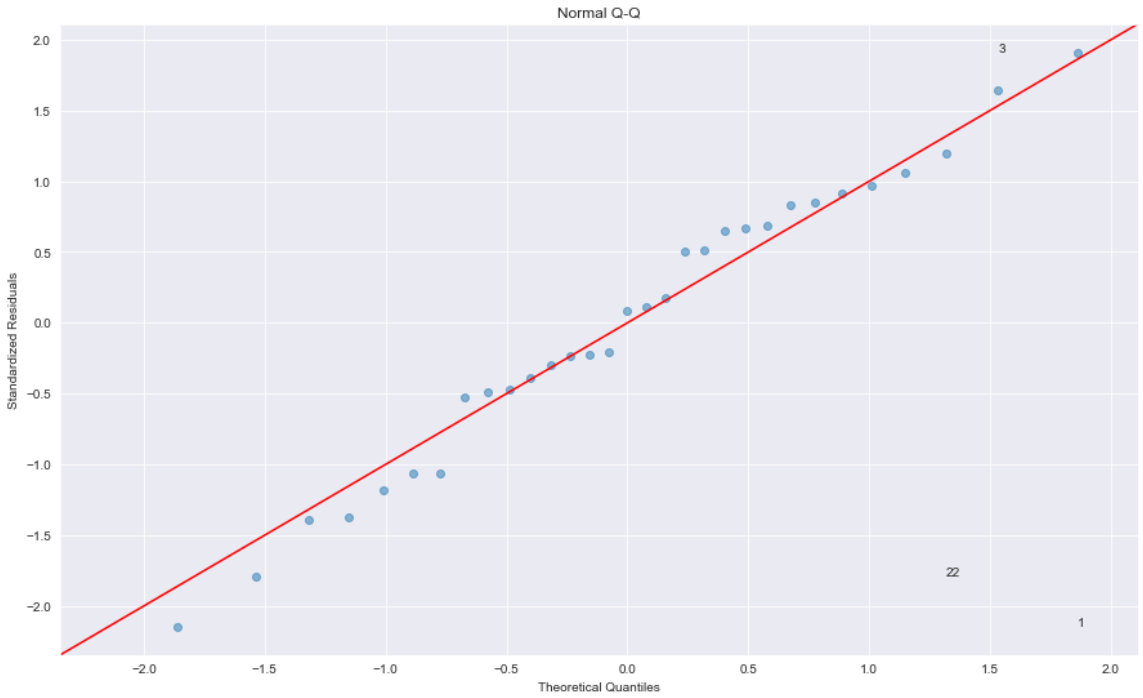
*Figure 3 - Summary of our primary model*

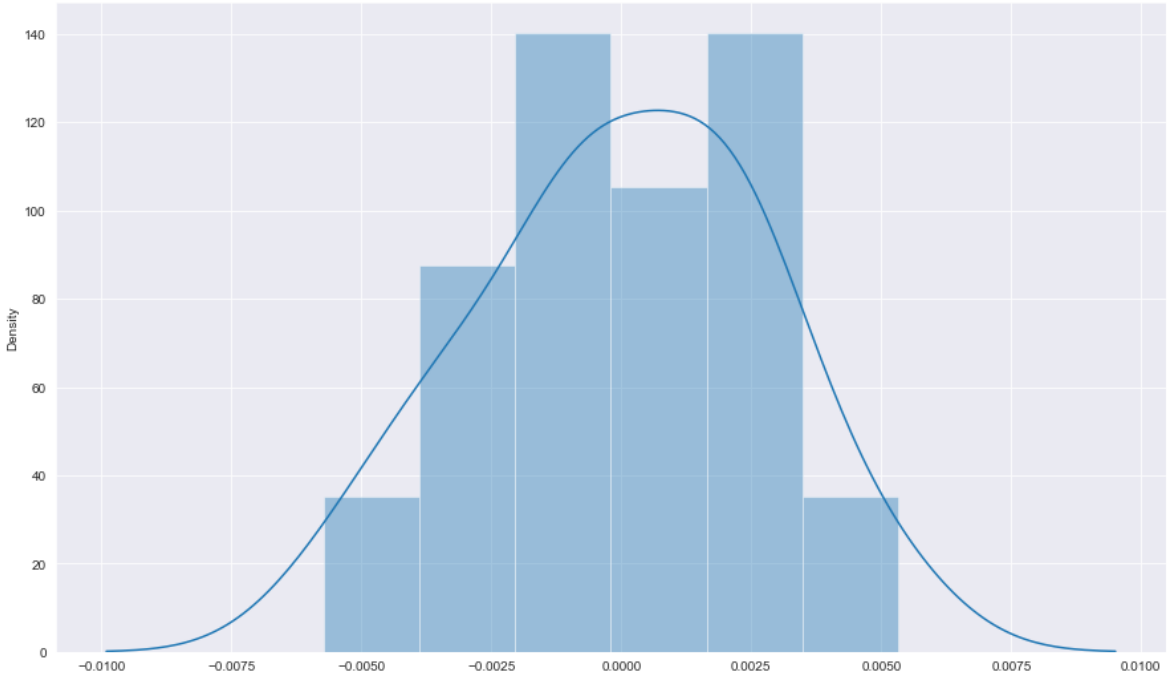
Figure 3 depicts the summary of our primary model, using the independent variables that were selected through stepwise regression. Finally, we have achieved a regression model with the following coefficients:

**Breast Cancer Incidence Rate (%) = -5.6317**
**+ 0.000006403 *Yearly Microplastics Emission (Tonnes)**
**+ 0.00003248 *AlcAmt (Litres per Adult per Year)**
**+ 0.0049 *FirstChildAge (Years)**
**+ 0.1554 *Reproductive Life Span (Years)**

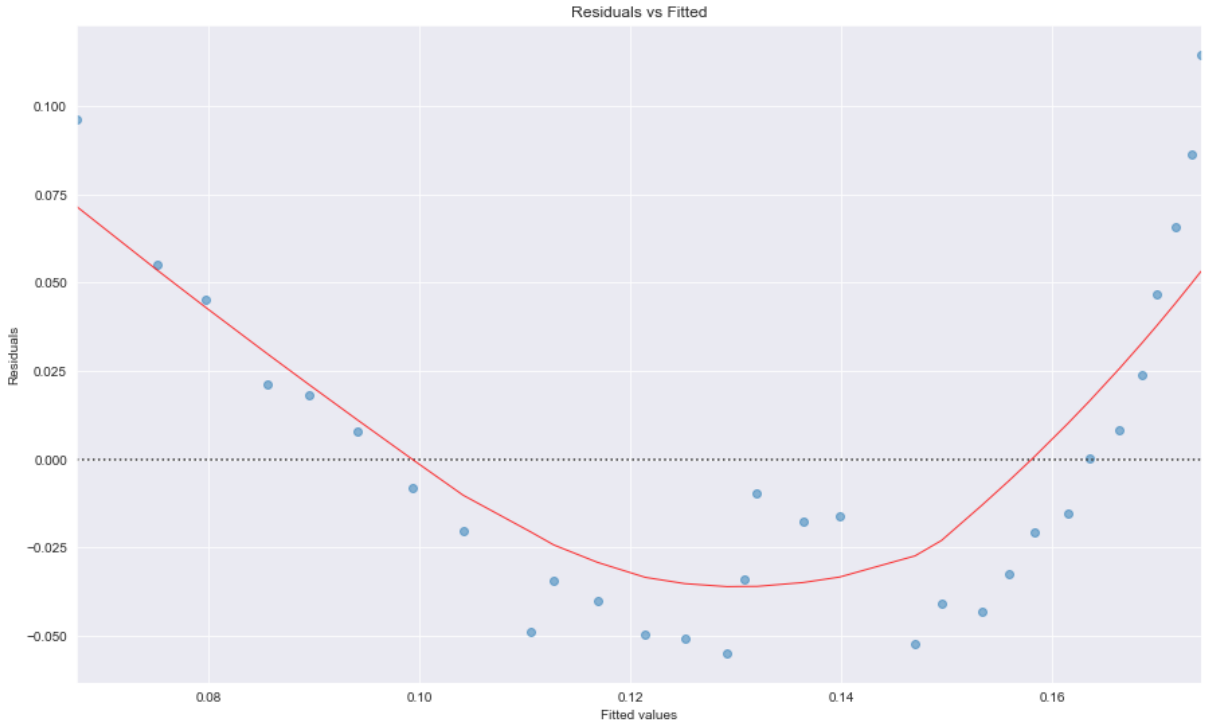
# Model Assumptions

## I. Normality Of Residuals



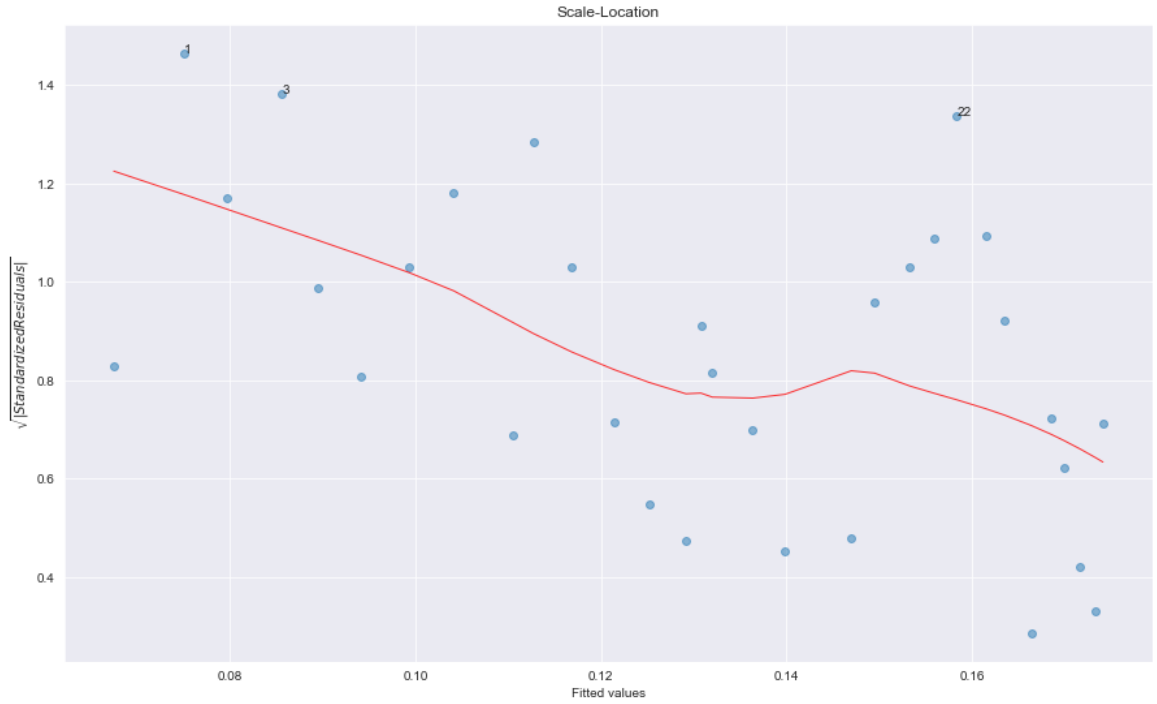



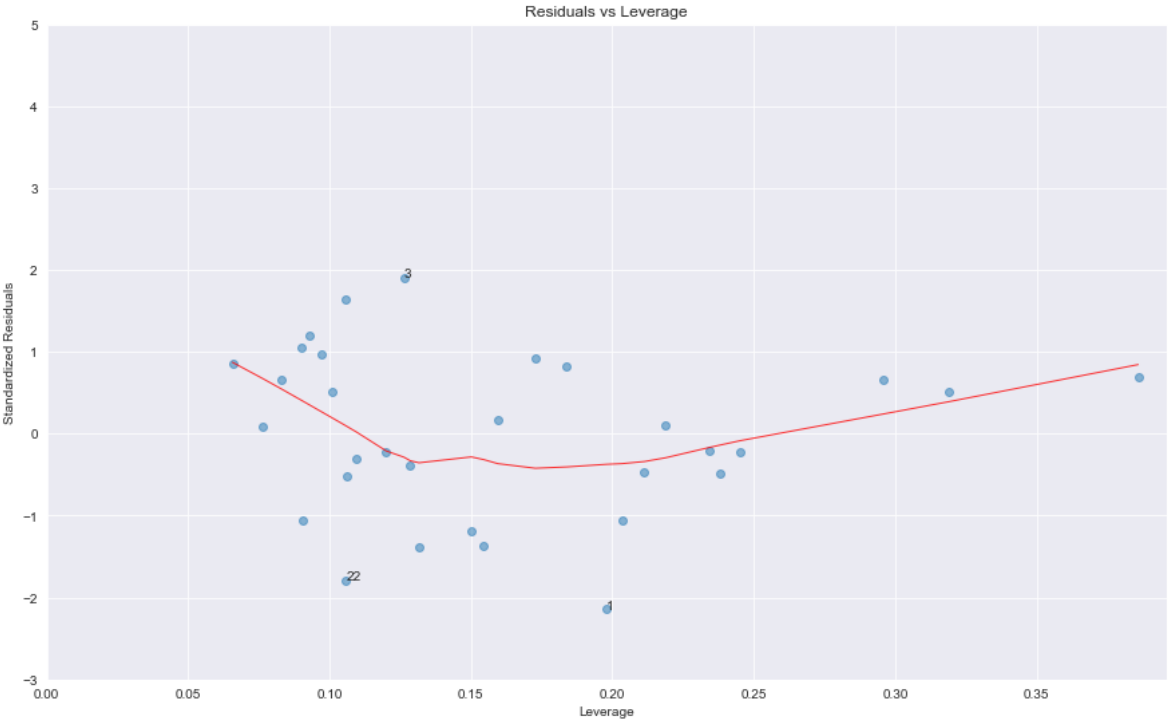
## II. Linear Association




This is typically assumed.

## III. Homoscedasticity



## IV. Independence

This is typically assumed.

## V. Multicollinearity

```
from statsmodels.stats.outliers_influence import variance_inflation_factor
{X.columns[i]: variance_inflation_factor(X.values, i) for i in range(1, X.shape[1])}
```

```
{'Yearly Microplastics Emission': 1.0378353751047031,
 'AlcAmt': 2.6735670576030035,
 'FirstChildAge': 2.673930725933204,
 'Reproductive Life Span': 0.00210184002190556}
```

Our VIF values of each variable is less than 5, and hence they are not collinear.

## Secondary Model

After performing a regression model, using Healthcare Expenditure as the Dependent Variable and Breast Cancer Incidence as the Independent Variable, we have obtained the following secondary regression model to be used. This secondary model is to help us identify the change in Healthcare Expenditure, given an increase in Breast Cancer Incidence in Singapore.

**Healthcare Expenditure (% of GDP) = 0.00002072 * Breast Cancer Incidence + 0.9334**

We will be touching on the specific values and conditions to be used for the Primary and Secondary Model in the next section.

# Results of our model

After having come up with the primary and secondary Regression Model, it is time to predict with our model and see what we can draw from them.

**Aim:** Find the cost incurred to the Singapore Government, given a 1% increase in Microplastics Emission.

| Step | Description of Objective | Results Obtained |
|---|---|---|
| 1 | Find out what constitutes a **1% increase** in Microplastics Emission.<br><br>$(1.01 * Xmean - Xmean)/Xmean$<br><br>Xmean = Average Microplastics Emission | **1% Increase** in Microplastics Emission constitutes an increase of **64.871 tonnes** of Microplastics |
| 2 | Given a **1% increase** in Microplastics Emission, find out the change in Breast Cancer Rate (Worldwide),<br><br>Input **increase of 64.871 tonnes** of Microplastics Emission into Primary Model | Breast Cancer Rate (Worldwide) **increased by 0.000415383%** |
| 3 | Given a **0.000415383% increase** in Breast Cancer Rate (Worldwide), we assume that Breast Cancer Rate in Singapore also increases by the same amount.<br><br>Now, find the increase in Breast Cancer Incidence (Total number) in Singapore. | Breast Cancer Incidence in Singapore **increased by 222** cases (rounded to whole number) |
| 4 | Given Breast Cancer Incidence in Singapore increased by **222 cases**, find out the increase in Healthcare Expenditure on Breast Cancer, as a % of GDP.<br><br>Input **increase of 222 cases** of Breast Cancer Incidence into Secondary Model | Healthcare Expenditure on Breast Cancer as a % of GDP **increased by 0.000172641%** |
| 5 | Given a **0.000172641% increase** in Healthcare Expenditure on Breast Cancer, find out the actual monetary value of this increase. | Healthcare Expenditure on Breast Cancer will **increase by a total of $58,697,930** for 222 breast cancer cases |

From the table seen above, we can finally conclude that given a **1% Increase in Microplastics Emission**, the Singapore Government can expect an increase of **222 Breast Cancer** Incidence in Singapore, and subsequently cause an increase in Healthcare Expenditure by **$59 million,** as depicted in Figure 4 below.

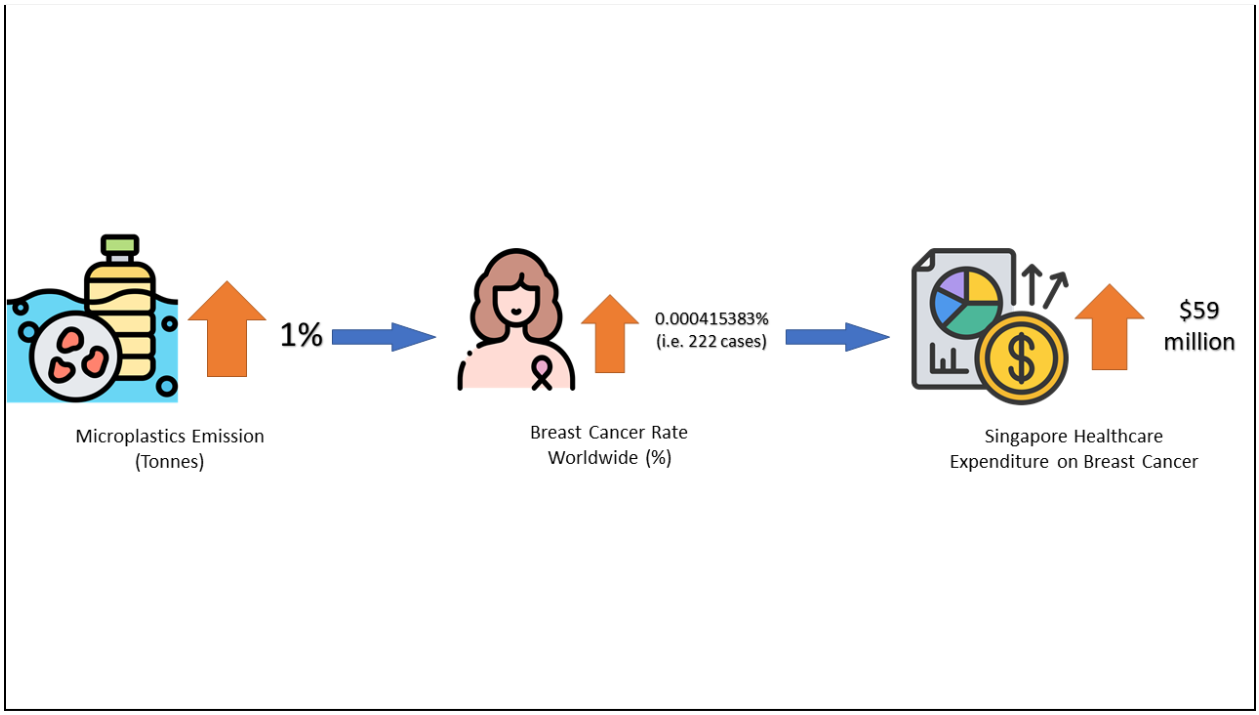



*Figure 4 - Impact of Microplastics Emission on Healthcare Expenditure in Singapore*

# Recommendations

The team will provide effective recommendations to the Singapore government to help **reduce the impact of microplastics in Singapore**.

There are 3 main stakeholders to be targeted in Singapore:

1. Producers
2. Merchants
3. Consumers

## Producers

### Single Use Plastic Tax/Policy Reform

National-level policies are mechanisms for a nation to steer its course and are essential in ensuring that such tools are being utilised in addressing the impact of microplastic. One of the recommendations we have is the implementation of **single use plastic tax** to essentially discourage producers in using plastic that is of one time use and potentially eliminate such sources of microplastic. This can be taken from past reference in the context of sin tax in Singapore, in particular the carbon tax that was first introduced on 1 January 2019. It was the first carbon pricing scheme in South East Asia (SEA) and we believe that with this past experience and case, it is very likely that Singapore could be yet again the first in SEA to impose such a tax and be the leader in paving the way for a greener future. (*Carbon Tax*, n.d.)

Such taxes can be implemented in phases to reduce the impact it has on local producers, as cost will inherently rise with such tax. The taxes will also need to ensure that it is calibrated in such a way that it does not significantly impact the standard quality of life and incur additional financial stress on the Singapore residents. This will also help producers to re-evaluate their manufacturing processes and speed up on their Research and Development to find new and greener ways in substituting plastic.

Likewise, merchants will be discouraged to sell products that are packaged in a single use plastic due to the additional cost incurred and find alternative brands to substitute it. Thus, the impact of tax will be relatively fast and immediate and changes can be observed as the tax is imposed.

| Single Use Plastic Tax | |
|---|---|
| **Strengths / Advantage** | **Weaknesses / Disadvantage** |
| • The effect of such tax will be **immediate** and the volume of plastic waste will gradually reduce over time due to the **increase cost**<br>• The revenue generated from the tax can then be used to fund more research and health expenditure.<br>• It potentially serve as a **deterrence** to single user plastic<br>• Make recycled material more **price competitive** with virgin plastic.<br>• Target an externality for which plastic tax is **runaway pollution** | • **Regressive Tax** - Undeniably **increase the cost of production** which will then pass on to consumers, which will have some financial impact on certain individuals.<br>• Companies might be reluctant to comply and **shift its production facility** to a country without such tax within close proximity. |

# Merchants

## GST Suspension/Reduction for Fish Imports in Selected Areas

Through the preliminary research and analysis, we have found that a major source of microplastic is from seafood. As seafood comprises a major diet component in Singapore, the reduction of the import of seafood will be difficult. As such, to reduce the consumption of microplastics by Singaporeans, the Singapore government can incentivise the merchants to import seafood from countries that produce and use lower levels of plastic in relation to other countries (such countries will, in turn, have lower levels of microplastics in their nearby seas).

Countries such as **Norway, Chile, Canada, Ecuador** and **Vietnam** are major exporters of seafood as well as produce lower levels of plastics in comparison to other countries (World Seafood Trade Map, 2019). As a result, the seafood imported from such countries will have lower levels of microplastic quantity in them (Plastic Pollution by Country, 2022).

The government can do so by creating a new Goods and Services Tax (GST) suspension/reduction scheme similar to the ones already implemented, as seen in the screenshot of the Inland Revenue Authority of Singapore (IRAS) website below.

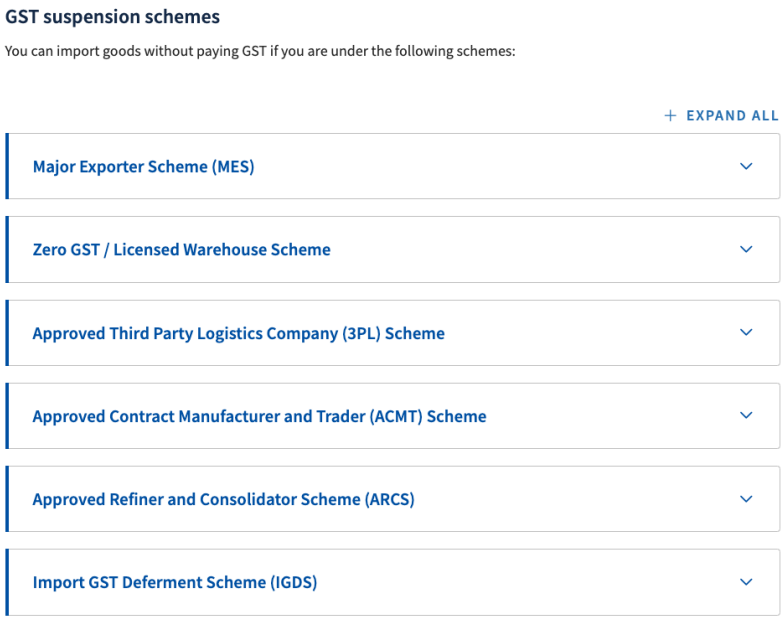



*Figure 5 GST Suspension Schemes available - Importing of goods*

This new GST suspension/reduction scheme would allow merchants to import seafood from countries with lower amounts of microplastics. Merchants would be incentivised to do so as this leads to lower cost.

| GST Suspension / Reduction for Fish Imports in Selected Areas | |
|---|---|
| **Strengths / Advantage** | **Weaknesses / Disadvantage** |
| ● **Immediate Impact** - Effectively reduce the ingestion of microplastic from seafood. | ● Diplomacy - It might potentially be seen as a **discriminating policy** in targeting certain countries.<br>● Might potentially **increase the cost** as some of these countries are located further away from the original source.<br>● The government would earn less tax revenue from seafood imports if this policy is effective |

### Market-Based Policy Instrument

Many of the "tragedy of the commons" environmental problems around the world are unresolvable through traditional forms of governance. However, if we were to combine both regulatory and market based incentives, we can observe some interesting developments in the reduction of plastic use.

This can be seen from the past cases in Singapore such as the BYO Singapore campaign where people are encouraged to bring their own container, reusable bags, bottle or container to retail outlets where incentive will then be offered to customers. In a short span of 4 months, they manage to reduce over 2.5 million pieces of plastic disposables. (*BYO Singapore*, n.d.)

This can be done in a few ways:

- Implement a convenience tax on merchants who default to using disposable containers even when they have in house seating, unless they have a reasonable recycling process
- Reward merchants which are zero waste, such as Scoop Wholefoods, Unpackt, by providing additional rebates. It is difficult to make such businesses sustainable, and the government can help these businesses by providing financial help. This approach kills two birds with one stone as it also encourages other businesses to be zero waste as well.
- Work together with major supermarkets to provide a service that allows consumers to purchase raw meat in reusable containers.

Hence, we believe that through incentive, it can serve as an extrinsic motivator in driving the population to reduce plastic usage and wastage.

| **Market-Based Policy Instrument** | |
|---|---|
| **<u>Strengths / Advantage</u>** | **<u>Weaknesses / Disadvantage</u>** |
| ● **Immediate Impact** - Overall plastic recycle rate will increase<br>● **Long-Term impact** - the rationale behind such initiative and the education values might have a delay in terms of the impact as we human need time to adapt and feel motivated not by extrinsic but the intrinsic motivator of doing such act | ● such incentive should not be utilised for a prolonged period of time as it will result in an incentivised base community where people will start to ignore the reason for such an initiative and instead commit solely for the incentive. |

# Consumers

## Using Science and Education Material to Inform the Public

Science is the best way we know to develop reliable knowledge. It's through intensive research, collaboration and cumulative processes of assessing evidence that leads to increasingly accurate and reliable information. Through the use of figures, trends and quotes, Singapore citizens can be well educated about the impact of microplastic and what role they can play in reducing cancer risks.

**Short term solution**
A campaign on educating the people to cut down on exposure to microplastic can be potentially critical in reducing the risk of health issues caused by microplastic, specifically breast cancer. The campaign can be a list of daily things we do and observe and explain why we should avoid or reduce such activities. One such example can be to avoid reheating of food or drink in plastic which include plastic tupperware, takeout boxes etc. Instead, transfer the food to a ceramic or glass container before heating it up. This is one of the many examples that we can preach to the public and encourage them to follow as the harm caused by microplastic is irreversible and will have a long lasting impact on one individual's health.

**Long term solution**
A citizen science solution can also be an alternative mode of educating the public, where we can take references from the collaboration of the two National Oceanic and Atmospheric Administration (NOAA) programs that kick started the Florida Microplastic Awareness Project in 2015. The project was both educational as it made the people living there more conscious of their plastic consumption and useful in collecting more microplastic data from coastal sites around the perimeter of Florida. Hence, in the context of Singapore, we can establish this initiative by working with the National Environmental Agency, Cancer Science Institute of Singapore, Singapore Centre for Environmental Life Sciences Engineering, as well as Grass Roots within the community to form a network where the grass roots will be trained in microplastic education and sampling. These grass roots will then be able to provide educational information and sampling protocols to the citizen volunteers through a rigorous training program. The sample collected by the citizen volunteer will then be aggregated and analysed on a publicly accessible map where everyone will see the impact and the volume of microplastic around the Singapore coastal area. We can leverage on certain environmental events such as the Earth Day and International Coastal Cleanup Singapore, to bring up the importance of having such an initiative and encourage individuals to pledge to reduce plastic waste.

The citizen science solution also provides a hands-on learning approach where studies have suggested that such a learning method will help to increase retention and allow them to practise their critical thinking skills and utilise the knowledge that they have accumulated during the training program, and with more recurring cycle, the better an individual will be in developing the intrinsic motivator for adopting a greener and more sustainable lifestyle.

| Using Science and education material to inform the public | |
|---|---|
| **Strengths / Advantage** | **Weaknesses / Disadvantage** |
| ● The Singapore population will be better educated about the microplastics and ways to tackle the microplastic pollution issue on an individual level<br>● Consumer action will play a vital role to reduce the microplastic level ingested in the body as well as in the environment. This will, in turn, reduce the overall breast cancer risk among Singaporean females | ● As these reforms will be educational rather than legal, some part of the population may act ignorant and not assist in playing their respective roles to mitigate the problem.<br>● Resistance by the public to shift to plastic alternatives as plastic is cheap and durable |

## Analysis of recommendations

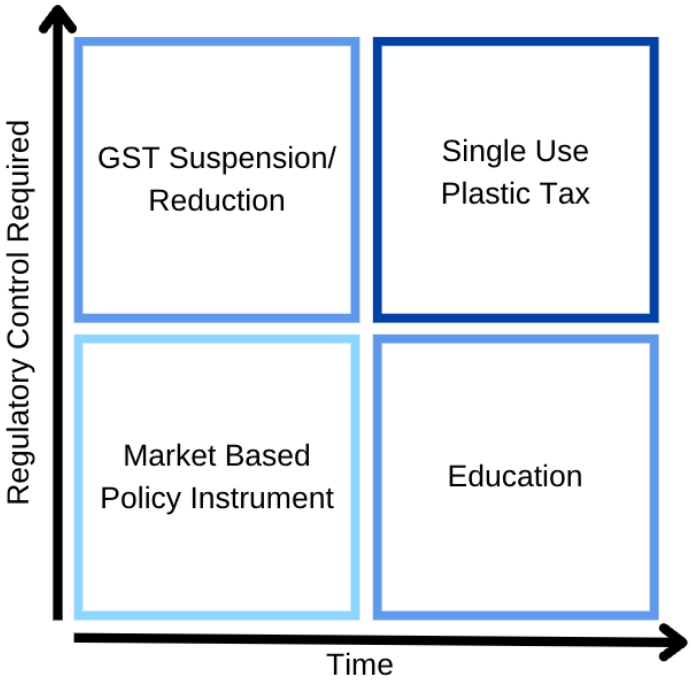



*Figure 6 Evaluation Matrix of Recommendations*

The chart above evaluates our recommendations based on the amount of regulatory control required for the implementation of the recommendation, as well as the amount of time required before the recommendation can be fully effective.

The tax based recommendations would require more regulatory effort, and perhaps receive backlash. The Single Use Plastic Tax recommendation policy would require time to be effective, as it targets microplastic production and it is often argued that tax is regressive in nature, thus careful consideration and calibration need to be taken into account.

The Market Based Policy Instrument and Education recommendations require less regulatory effort. The Market Based Policy Instrument recommendation would require less time to be effective as consumers would be incentivized by the money savings, and the education recommendation would require more time to be effective, as it requires the consumers to internalise the habits and be intrinsically motivated to practice habits that will prevent microplastics from entering their body.

# Further Work

In our report, we analysed the impact that microplastics would have on breast cancer incidence rate in Singapore, and the additional healthcare costs associated with it. However, we also realised that there would be soft costs attached to the increased breast cancer incidence. We would like to research more about the impact of increased breast cancer, and how that would affect Singaporeans.

Certain hypotheses that we have include a decrease in birth rate, which the Singapore government is highly concerned about. According to the 2019 Singapore Cancer Registry Annual Report, breast cancer is the most common cancer affecting female Singaporeans aged 30-39. Given that the median age of first-time moms in Singapore is 30.3, and the number of women giving birth after 40 doubling over the past 30 years (Gan, 2016), it is a cause for concern as cancer treatments can affect fertility. Radiation therapy and chemotherapy can cause infertility, so much so that it is recommended for females to freeze their eggs before undergoing such treatments, if they plan to have children in future (USCFertility, 2022). However, it does not guarantee that the eggs will be viable. In general, only 75% of the eggs will survive the freezing and thawing process, and the success chances of a live birth is 18-32%, depending on the age of the woman when the eggs are frozen (CareFertility, 2022). This means that an increase in cancer that requires fertility affecting treatment may negatively affect the birth rate in Singapore, which is a pressing concern to the government, as it causes economic stress as the demographic changes to an ageing population (Khoo, 2016).

In fact, our report only covers the impact of microplastic on breast cancer, but research does show that it may cause other cancers. Collectively, this may pose a greater impact on Singapore than we have discovered.

# Call to Action

Microplastics are increasing globally at an exponential rate. According to a study, almost 400 million tonnes of plastic are produced each year, a mass projected to double by 2050 (XiaoZhi Lim, 2019). Through the analysis, as microplastic pollution contributes to increased risk of breast cancer among females in Singapore, it is vital to take necessary steps to reduce the problem now, before the issue becomes impossible to control.

## Aon Center for Innovation and Analytics (ACIA)

The impacts of hazardous chemical and microplastic on the physiology of both human and marine organisms is still nascent and heavy emphasis needs to be placed to accelerate the research on microplastic have on human health. Further research is critical in obtaining a more accurate assessment of exposure to microplastic and thus our call to action for ACIA would be to build up a more robust research capability that prioritises on the effect of microplastic have on human health.

Several factors also needed to be taken into consideration due to the strong relation and alignment with cancer. Our model is limited by the fact that we pulled in data from various sources, and most of our justification and information are gathered from secondary research. We believe ACIA will have the resources to engage researchers to conduct primary research as the researcher will be fully involved in the data collection process and the collected data will have its authenticity, specific nature and up to date. Likewise, due to the limited information on the time lag of each of the predictors, we believe that the result could be slightly deviated from the expected result. Thus, a follow up on consumers through a time period is critical in analysing the amount of microplastic present in them and comparing that with the individual's various health indicators. ACIA can then commence the analytics process with better data, and can even venture on to explore the impact of microplastics on other indicators of human health, such as other cancers, fertility and child development.

# References


*Alcohol consumption and survival after breast cancer diagnosis in Japanese women: A prospective patient cohort study*. (n.d.). NCBI. Retrieved April 3, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6853331/

Appiah, D., Nwabuo, C., & Ebong, I. (2021, Apr 6). *Trends in Age at Natural Menopause and Reproductive Life Span Among US Women, 1959-2018*. JAMA Network. https://jamanetwork.com/journals/jama/fullarticle/2778126

*Association between body mass index and breast cancer risk: evidence based on a dose–response meta-analysis*. (2018, January 18). NCBI. Retrieved April 3, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5783020/

*Breast Cancer*. (n.d.). Singapore Cancer Society. Retrieved April 3, 2022, from https://www.singaporecancersociety.org.sg/learn-about-cancer/types-of-cancer/breast-cancer.html

*Breast Cancer – Causes, Symptoms & Treatment*. (2021, March 31). Gleneagles Hospital. Retrieved April 2, 2022, from https://www.gleneagles.com.sg/facilities-services/centre-excellence/cancer-care/breast-cancer

*Breast Cancer Risk: Age at First Childbirth*. (n.d.). Susan G. Komen. Retrieved April 3, 2022, from https://www.komen.org/breast-cancer/risk-factor/age-at-first-childbirth/

*BYO Singapore*. (n.d.). BYO Singapore – Bring Your Own Bag, Bottle or Container. Reduce Plastic Disposables and Get Rewards. Retrieved April 3, 2022, from http://www.byosingapore.com/

*Carbon Tax*. (n.d.). National Climate Change Secretariat. Retrieved April 3, 2022, from https://www.nccs.gov.sg/singapores-climate-action/carbon-tax/

CareFertility. (2022). *8 common questions about freezing eggs for a later pregnancy*. Care Fertility. https://carefertility.com.au/resources/blog/8-common-questions-about-freezing-eggs-for-a-later-pregnancy

Centers for Disease Control and Prevention. (2021, September 20). *What Are the Risk Factors for Breast Cancer?* CDC. https://www.cdc.gov/cancer/breast/basic_info/risk_factors.htm

Galloway, T. (2020, July 22). *Plastics found in sea-bed sharks*. ScienceDaily. https://www.sciencedaily.com/releases/2020/07/200722083807.htm

Gan, E. (2016, December 27). More women in Singapore giving birth in their 40s. *The Straits Times*. https://www.straitstimes.com/singapore/health/more-women-in-singapore-giving-birth-in-their-40s

*Health Factsheet*. (2012, July 27). National Registry Of Diseases Office. Retrieved April 3, 2022, from https://www.nrdo.gov.sg/docs/librariesprovider3/Publications-Cancer/health_factsheet_breast_2012jul.pdf?sfvrsn=0

Heather A, L. (2021, December). *Discovery and quantification of plastic particle pollution in human blood*. https://www.sciencedirect.com/science/article/pii/S0160412022001258.

Hoon, K. K., Stock, M., Singh, K., & Perry, M. (2020, December 8). *WIDER IMAGE - How much plastic are you eating?* Thomson Reuters Foundation News. Retrieved April 3, 2022, from https://news.trust.org/item/20201208090301-obmrm

*How harmful are microplastics? — Science Learning Hub*. (2019, August 30). Science Learning Hub. https://www.sciencelearn.org.nz/resources/2809-how-harmful-are-microplastics

Khare, E. (2020, October 19). *14 Million Tons of Microplastic are on the Ocean Floor - Science in the News*. Science In The News, Harvard University.

https://sitn.hms.harvard.edu/flash/2020/14-million-tons-of-microplastic-are-on-the-ocean-floor/

Khoo, V. (2016, July 26). Singapore's low birth rate poses economic problems, as Asia's demographic stress rises. *CNBC*. https://www.cnbc.com/2016/07/26/singapores-low-birth-rate-poses-economic-problems-as-asias-demographic-stress-rises.html

Kwon, W., Kim, D., & Kim, H.-Y. (2022). Microglial phagocytosis of polystyrene microplastics results in immune alteration and apoptosis in vitro and in vivo. *Science of The Total Environment*, *807*(2), 1. https://www.sciencedirect.com/science/article/abs/pii/S0048969721058952?via%3Dihub

Lee, H. W. (2022, Jan 3). *BREAST CANCER STATISTICS IN SINGAPORE 2021*. BREAST CANCER STATISTICS IN SINGAPORE 2021. Retrieved 4 3, 2022, from https://www.bestinsingapore.co/breast-cancer-statistics-singapore/

Leslie, H. A., Velzen, M. J. M. v., Brandsma, S. H., Vethaak, D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. *Environmental International*, *107199*(24 March 2022), 1. https://www.sciencedirect.com/science/article/pii/S0160412022001258

Lim, X. (2019, May). *Microplastics are everywhere — but are they harmful?* https://www.nature.com/articles/d41586-021-01143-3.

*Microplastics: sources, effects and solutions* | *News*. (2018, November 22). European Parliament. Retrieved April 3, 2022, from https://www.europarl.europa.eu/news/en/headlines/society/20181116STO19217/microplastics-sources-effects-and-solutions

Nordqvist, C. (2019). *10 effects of smoking cigarettes*. Medical News Today. Retrieved April 3, 2022, from https://www.medicalnewstoday.com/articles/324644#secondhand-smoke

Nortajuddin, A. (2020, October 19). *Breast Cancer Amid The Pandemic*. The ASEAN Post. Retrieved April 3, 2022, from https://theaseanpost.com/article/breast-cancer-amid-pandemic

Novak, A. (2018, February 6). *Tackling Microplastics on Our Own*. Wilson Center. Retrieved April 3, 2022, from https://www.wilsoncenter.org/article/tackling-microplastics-our-own

*Plastic Pollution by Country 2022*. (n.d.). World Population Review. Retrieved April 3, 2022, from https://worldpopulationreview.com/country-rankings/plastic-pollution-by-country

Ragusa, A., Svelato, A., & Santacroce, C. (2021). Plasticenta: First evidence of microplastics in human placenta. *Environment International*, *146*(January 2021), 1. https://www.sciencedirect.com/science/article/pii/S0160412020322297

Rodgers, K. M., Udesky, J. O., Rudel, R. A., & Brody, J. G. (2017, October 6). *Environmental chemicals and breast cancer: An updated review of epidemiological literature informed by biological mechanisms*. PubMed. https://pubmed.ncbi.nlm.nih.gov/28987728/

Stoll, B. A. (1998). Western diet, early puberty, and breast cancer risk. *Breast Cancer Research and Treatment*, *49*, 187-193. https://link.springer.com/article/10.1023/A:1006003110909

Terry, M. B. (n.d.). *Alcohol Intake and Breast Cancer Risk: Weighing the Overall Evidence*. NCBI. Retrieved April 3, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3832299/

The Premenopausal Breast Cancer Collaborative Group. (2018, November 8). *Association of Body Mass Index and Age With Subsequent Breast Cancer Risk in Premenopausal Women.* https://jamanetwork.com/journals/jamaoncology/fullarticle/2685650.

Tiersten, A. (2021, April 16). *Smoking and Breast Cancer: Are They Linked?* Healthline. Retrieved April 3, 2022, from https://www.healthline.com/health/understanding-breast-cancer/can-smoking-cause-breast-cancer

USCFertility. (2022). *Egg Freezing for Cancer Patients - Fertility Preservation*. USC Fertility. https://uscfertility.org/fertility-preservation/egg-freezing-for-cancer-patients/

Verla, A.W. (2019). *Microplastic–toxic chemical interaction: a review study on quantified levels, mechanism and implication*. https://link.springer.com/article/10.1007/s42452-019-1352-0.

*Why Singapore spends so much on cancer treatment and how changes to MediShield Life hope to address this*. (2021, August 17). National Dental Centre of Singapore. Retrieved April 3, 2022, from https://www.ndcs.com.sg/news/announcements/why-singapore-spends-so-much-on-cancer-treatment-and-how-changes-to-medishield-life-hope-to-address-this

*World Seafood Trade Map 2019*. (n.d.). RaboResearch. Retrieved April 3, 2022, from https://research.rabobank.com/far/en/sectors/animal-protein/world-seafood-trade-map.html

Yan, Z., Liu, Y., Zhang, T., Ren, H., & Zhang, Y. (2021, December 22). *Analysis of Microplastics in Human Feces Reveals a Correlation between Fecal Microplastics and Inflammatory Bowel Disease Status*. ACS Publications. https://pubs.acs.org/doi/10.1021/acs.est.1c03924