IMPLICATIONS OF IMO 2020 ON FUEL MARKETS AND THE ENVIRONMENT

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Abstract

This work studies the effect of a new sulfur regulation introduced by the International Maritime Organization on January 1st, 2020. The goal of this regulation was to reduce the amount of sulfur in emissions from large ocean going vessels to 0.5%. A reduction in bunker demand was attributed to an increase in diesel demand due to the fact that a middle distillate (combination of diesel and residual) is most likely to pick up slack in the market. Changes in price and criteria pollutants were analyzed. Three scenarios were investigated, a 50%, 75% and 100% reduction in bunker demand. Preliminary analyses showed that sulfur oxides would have the greatest reduction, followed by carbon monoxide. Data after January 2020 was going to be used as a post analysis to see how the respective markets were affected. Due to the oil price war between the Saudis and Russians, and the Coronavirus, oil consumption data has been tainted, making an analysis of the effects nearly impossible. Confounding factors were discussed and related to the analysis.

1. Introduction

Emissions over international waters have been an issue since the beginning of the industrial revolution. There is a benefit to pollute, especially when there is no international regulatory body looking over emissions from ships. This has led the industry to adopt residual bunker fuel. This fuel is extremely high in criteria pollutants, specifically sulfur oxides. These have an adverse effect on the environment and public health, particularly for those living near major shipping lanes or coastlines. Historically, there has not been an organization that regulated the shipping industry. The difficultly of regulating such an industry is very high because monitoring practices are time consuming and expensive. The International Maritime Organization (IMO) has been around for over seventy years, and they have the vested right to create regulations that member states of the United Nations have to follow and enforce. A new regulation going into effect January 1st, will be analyzed. The regulation will now be referred to as IMO 2020. The sulfur content in international shipping (regardless of sector), has to decrease from 3.5% to 0.5%. I will perform a preliminary analysis of what the effects will be on markets and the environment, which will be followed up after the regulation is established, by another analysis.

1.1: Shipping and Polluting

Cargo shipping is the most widely used mode of transportation for international trade. More than 80% of all goods are on a containership at some point during their lifecycle. Container ships sail in international waters; there was little regulation about the fuels and engines that they used. Unrestricted operations have led to business practices that endanger the environment and public health. A containership carrier can emit as much as millions of diesel cars annually, which makes this sector a large contributor of greenhouse gases (GHGs) and one of the largest polluters of criteria pollutants in the world (Halff et al. 2017). Beyond, the industry accounts for nearly 13% of total greenhouse gas emissions, 13% of NO_x and 15% of SO_x (IMO 2015). Shipping however, is the most cost-effective and energy-efficient method per metric ton per mile because of the sheer weight that these ships move.

Sulfur in the form of sulfur oxides (SO_x) has a direct influence on the health of the environment and public. Sulfur oxides have been linked to premature deaths from stroke, asthma, cardiovascular disease, lung cancer and pulmonary disease. Populations that live by major shipping lanes are at the highest risk. Further, once released in the atmosphere, these molecules bind to water to create acid rain, which is detrimental to crops, forests, aquatic species and the acidification of the ocean.

1.2: Brief History of IMO

There was a lack of a regulatory bodies to monitor practices on the oceans. After World War II when the United Nations was created, many agencies were created. The IMO was created by the U.N. in 1948, and started operating in 1958. The aim of the organization is:

> "to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships"

as stated in the Geneva Conference of 1948, Article 1(a) (United Nations 1958). This United Nations specialized agency has the power vested in them to create regulations for the shipping industry. Early regulations focused on safety and congestion near coastlines until the Torrey Canyon disaster in 1967. Approximately 120,000 tons of oil was leaked into the North Sea. At the time, this was the worst international oil spill. The IMO started to focus on operational and accidental pollution from vessels. The International Convention for the Prevention of Pollution from Ships was created in 1973 and modified in 1978 (MARPOL 73/78). This was a powerful tool that the IMO could use because, "it covers not only accidental and operational oil pollution, but also pollution from chemicals, goods in packaged form, sewage, garbage and air pollution" (IMO 2019). Over the course of its lifetime, the IMO has adopted stricter and stricter regulations pertaining to all aspects of the industry, not just pollution. In 2005, sulfur oxide regulations came into effect under Annex VI of MARPOL. Since the IMO is a component of the United Nations, the organization seeks to meet the 2030 Agenda for Sustainable Development, and is developing more stringent regulations.

1.3: The Goals of IMO 2020

The goals of IMO 2020 are relatively straightforward. They targeted the fuels that large ocean going vessels can use, unless they install scrubbers. IMO wanted to decrease the sulfur content in fuels from 3.5% to 0.5%. This in turn, was to create less atmospheric sulfur oxides as a result of engine combustion. Conclusively, the goal of the regulation was to push these fuel users towards cleaner fuels or scrubbers, which in turn would emit less pollutants than before.

1.4: IMO 2020, Methods of Compliance and Enforcement

IMO 2020, set to go in effect January 1, 2020, is the most comprehensive sulfur regulation thus far. This eliminates bunker fuel as a standalone fuel that vessels can use, so there will be a switch to an alternative fuel or the installation of scrubbers. The most likely fuel that will pick up the slack will be diesel or some middle distillate that is a combination of bunker and diesel fuels. The other option is to install scrubbers so that bunker fuel can still be used, but the emissions will only contain 0.5% sulfur. The upfront capital cost of a scrubber ranges from two to three million, with an average cost of around fifty dollars per kW of engine power (DEFLT 2016). Compared to buying a new engine to utilize a new type of fuel, this is an attractive option for businesses. There are three different types of scrubbers: open loop, hybrid and closed loop. The open loop scrubber pollutes more than just emitting the sulfur into the air. Lucy Gilliam works for a Brussels NGO and stated “wildlife in these area is likely to be far more vulnerable to the effects of having ships discharging huge volumes of acidic, polluted, warm water from scrubbers” (Crisp 2019). Hybrid and closed loop scrubbers are much better for the environment as they keep some and all of the wastewater aboard, respectively.

All of the member states are obligated to ratify the IMO regulation. The reality is that some countries are going to better at monitoring and enforcing. Beyond that, flag states, which is the country that a ship is registered to (and which flag is flown) have different motives for enforcement. Further, one can fly a flag of convenience, meaning that the owner of a vessel can choose which flag they want to fly. Currently, Panama and Liberia are the top flag of convenience states in the world, with over 25% of ships registered to them. These two countries have little infrastructure to monitor and enforce the IMO regulations. There could be a move to reregister ships under countries that do not take enforcement of IMO 2020 seriously, which would undermine the implementation of this regulation. An example of this would be Bolivia; it is landlocked yet there has been an increase in the number of vessels that fly their flag. Further, nearly three quarters of the world's merchant fleet flies the flag of a member state that is not listed (Scheiber 2013).

2. Background

2.1 Previous Literature

Previous research done on the implications of the IMO 2020 regulation is hard to find, but two major studies have been conducted. The first was performed by the Energy Information Administration (EIA) in 2019. They found that finished product pricing may start changing in mid 2019 (EIA 2019). The share of high-sulfur residual fuel oil (HFO) will drop from 58% in 2019 to only 3% in 2020, but could potentially rebound up past 20% in the years after. Due to this collapse in bunker demand, the global prices for light and low-sulfur products will increase because demand will move to one of those products. The administration suggests that the effects of the regulation will be much more pronounced on the product market rather than the crude oil market. What creates even further uncertainty regarding the regulation is that most shippers sign bunker fuel contracts with suppliers that have operations across many ports. The amount of fuel that is compliant with IMO 2020 is uncertain until 2020 comes around and we see the demand response.

Implications of IMO 2020 go further than just affecting energy markets. There are "three factors that discourage a prompt response to a new policy: financial burden of premature compliance, financial risks stemming from market uncertainty and regulatory uncertainty" (Halff et al. 2019). Premature compliance could potentially be devastating for businesses if the costs of alternative fuels does not increase significantly. If one were to comply through the use of scrubbers rather than an alternative fuel, this could be even worse. The upfront capital expenditure that the scrubbers require could be useless. The regulation itself creates market uncertainty because shippers have absolutely no incentive to use the fuels that cost more until they are required to do so. Regulatory uncertainty stems from the fact that the IMO can create new regulations at any time they see fit. If a business were to comply and meet IMO 2020, a new regulation that regulates other pollutants could be passed, influencing the decision a company made to meet IMO 2020.

The likely scenario is that shipping companies will switch to a middle distillate (diesel) because it is the most versatile of the refined products (Halff et al. 2019). Due to the viscosity requirements of container ship engines, new bunker fuels are most likely going to be new low-sulfur fuel oil (LSFO) blends. This will most likely create a situation similar to the 2008 Oil Rally; imbalances in supply and demand resulted in a price premium for sweet crude, such as West Texas Intermediate (WTI) and North Brent. Both of these areas have higher yields of diesel and other refined light products (Halff et al. 2019). At the moment, bunkers account for 4-7% of oil demand globally. With the implementation of IMO 2020, HFO consumption will most likely drop by 75% or more, leaving a large amount of demand to be filled by other fuels.

2.2 Known Elasticities

There has been much research in the past to ascertain what the elasticities are for the different refined products of crude oil. Rather than trying to derive these same elasticities, I pulled them from sources and checked the values they got against other studies.

Price elasticity of demand for diesel is very inelastic with a value of -0.07 (Dahl 2012). A change in price will have a minimal effect on the quantity demanded, but at large volumes of quantity, there could be an overall significant change in the total value. Gasoline price elasticity has an incredible amount of variation, but a meta-analysis of gasoline price elasticities found an average of -0.27, which is much more elastic than diesel (Levin et al. 2017). Gasoline has a wide variety of applications, especially outside of the maritime sector. Those who recognize the price signal by an increase in price can decrease their consumption accordingly. It may be more accurate to stay on the low end of the estimations, such as having a -0.09 price elasticity of demand (Levin et al. 2017). Elasticity information for residual bunker fuel is very difficult to find and often proprietary. The best estimate that I could find estimates that the residual fuel price elasticity of demand is -0.33 (Mazraati 2011). The elasticity is more elastic than the other price elasticities, which represents the options that vessels have between their fuels. The elasticities for gasoline and diesel also have land transportation included in them, so the bunker elasticity may be the most accurate for sea going vessels. This elasticity will help these companies shift their use of residual fuels to either distillate, gasoline or another refined product.

The last elasticity needed is a supply elasticity for crude oil. This cannot necessarily be derived as easily as other supply elasticities later in this analysis, so literature was reviewed to obtain an elasticity. It was found that the crude oil supply elasticity is 0.25, accounting for the global financial crisis in 2008 and policy differences between countries (Adelaja 2018).

3. Methodology

Due to the collapse in demand for bunker fuel from IMO 2020, there is going to be a shift in the market towards an alternative fuel. Modeling this change will be helpful to analyze the effectiveness of this new regulation. Elasticities are an essential tool to use because they model the sensitivity of one variable against another, in this case, quantity and price.

This analysis utilizes a three step system to calculate the effect of the IMO 2020 regulation on fuel markets. Fuel supply elasticities are scarce in literature, so they were estimated using the basic elasticity formula manipulated in multiple ways. Second, using those elasticities in conjunction with an equilibrium displacement model, changes in the quantity of refined products was calculated. Changes in emissions and criteria pollutants were then calculated from the change in quantity shifting away from residual fuels, towards other refined products.

3.1 Supply Elasticities

Elasticities measure the responsiveness of one variable to a change in the other. In regards to this analysis, price and quantity are used. Quantity traditionally drives price, but price and quantity can be interchanged to investigate how they affect each other. The standard elasticity formula is

$$\mathcal{E} = \frac{\%\Delta Quantity}{\%\Delta Price}$$

This equation can be augmented to show that

$$\mathcal{E} = \frac{\frac{\Delta Q}{Q_0}}{\frac{\Delta P}{P_0}}$$

And rearranged to

$$\Delta Q = \frac{\Delta P * Q_0 * \mathcal{E}}{P_0}$$

For every barrel of crude oil, there is a fixed distribution of the refinement of the finished products. The shares of finished products in regards to a barrel of crude oil can be found on the Energy Information Administration website. The price of crude oil is an aggregation of the prices and shares of refined products, respectively summed.

$$P_{Crude} = P_{Gasoline} * \%Share_{gasoline} + P_{Diesel} * \%Share_{Diesel} + P_{Residual} * \%Share_{Residual} + ...$$

For some change in the price of one fuel, there will be a change in the price of crude oil, all other parameters held constant. Now everything is acquired to estimate supply elasticities. Once a particular price is tweaked, $\Delta P_{Crude}, Q_{0_{Crude}}, P_{0_{Crude}}$ *and* $\mathcal{E}_{Supply_{Crude}}$ are all known parameters and can be fed back into the ΔQ equation to calculate how that price change will affect the quantity supplied of crude oil. To find $\Delta Q_{Refined\ Product}$, multiply ΔQ_{Crude} by the share of this respective refined product in the refinement of a barrel of crude oil. Variables were calculated for the major fuels such as gasoline, diesel and residual. The data specific to each fuel can be inputted into the standard elasticity formula to calculate the supply elasticities.

3.2 Equilibrium Displacement Model (EDM)

Markets will always try to move towards an equilibrium price when unrestricted, with a respective equilibrium quantity. Knowing that the demand for bunker fuel is going to most likely shift to a different refined product, predicting the new equilibrium points in each market is essential to this analysis. "EDMs are essentially logarithmic differential equations characterizing comparative statics of a system of equations describing movement from one equilibrium to another resulting from a change in one or more of the parameters of the equation system" (Wohlgenant 2011). The advantages of using this type of model is that it allows for the use of partial elasticities, relative shares and the use of previously estimated elasticities. E will denote a relative change (% change).

$$EQ = \frac{\Delta Q}{Q} \cong \Delta \log{(Q)}$$

The equation used in this analysis was

$$EQ_D = \eta EP - \eta \delta$$

where EQ_D represents the relative change in demand, η is the price elasticity of demand for Q and δ is the relative change in demand ($\delta > 0$ describes a vertical, upward shift in demand: price) (Wohlgenant 2011). EP needs further refinement, and can be shown as

$$EP = \frac{\varepsilon k - \eta\delta}{\varepsilon - \eta}$$

Plugging this back into the EQ_D renders

$$EQ_D = \eta * \frac{\varepsilon k - \eta\delta}{\varepsilon - \eta} - \eta\delta$$

where k shows the relative change in supply and ε is the elasticity of supply. Supply will follow demand, because to create more of a refined product, you have to use more crude oil since the refinement ratios are fixed. This means that the relative change in supply will be zero. This equation can be simplified to

$$EQ_D = \frac{\eta^2\delta}{\varepsilon - \eta} - \eta\delta$$

What this really represents is

$$\Delta\log(Q) \cong \frac{\eta^2\delta}{\varepsilon - \eta} - \eta\delta$$

All of the parameters in the equation are known, except for δ, but this can be considered the independent variable. Looking at a relative change in the price of the refined product, this equation can be used to estimate the new equilibrium points as a share of the demand shifts into that particular refined product's market.

3.3 Emissions and Criteria Pollutants

Once the new equilibrium points are known for different fuels, the change in emissions and criteria pollutants can be calculated as a function of change in quantity of fuel. The result of the EDM is inherently a change in quantity, so that output can immediately be used an as input to find how pollution will change from the levels being currently emitted. Data for the emissions of marine engines was supplied by the California Air Resources Board (CARB) report on gaseous emissions from marine engines (Agrawal 2008). The main issue is that price and quantity units are not consistent between refined products, and the energy content differs between a barrel of refined products. Therefore, all of the quantity units are switched into barrel of oil equivalent (BOE), to account for the different energy contents. Consumption was then calculated for an entire year, and the resulting changes in emissions form utilizing different fuels shows a difference over one year.

The statistics for marine engines came in terms of different power loads. No engine is run at 100%; the maximum is usually around 60% (Halff et al 2017). This is called slow steaming; the act of deliberately slowing down your ship to a fraction of the total speed and output, to increase efficiency. A study conducted in 2013 sought to estimate the costs and benefits of slow steaming under various assumptions. They found that the practice of slow steaming paid off under then prevalent conditions but that ‘extra slow steaming’ was most beneficial, cutting total costs by 20% and carbon dioxide emissions by 43% (Maloni 2013). The statistics for greenhouse gases and criteria pollutants were averaged between an engine at 40% and 60% load. These were then multiplied by the BOEs for each fuel, to deliver pollution statistics for the fuels. It is important to note that an engine can only take one type of fuel, so different engines were used for different fuels.

4. Data Generating Process

Most of the data used in this analysis is scraped off of the EIA website, through reports and their interactive table viewer. Production quantities will be used as proxies for consumption quantities, because it is difficult to trace consumption and much easier to keep track of production. Nearly every year, there is less than a 0.5mbpd difference between consumption and production, out of around 100mbpd. Refinery output of petroleum products was taken from the EIA International Energy Statistics for the year 2015, because that was the most recent year that there was data available for each fuel. I identified the three major fuels currently in use: gasoline, diesel and residual. I grouped the rest together as refined products and included the crude oil production quantity. The EIA 2019 Annual Energy Outlook and 2019 International Energy Outlook associated the current prices with the quantities of 2015, creating a minor counterfactual. It is important to look at global production, rather than domestic production in the United States, because most of the fuel produced would be left out. The most recent year that has global production statistics is 2015. All of the production quantities were converted to barrel of oil equivalent (BOE) because of the differing energy content of each refined product. This allowed for the analysis between fuels. Further, spot prices are taken from the EIA website to check against prices in both of their annual reports.

Data for the emissions analysis came from CARB. Specific values for each pollutant were scraped from the Ocean-Going Vessels Emission Measurement Reports and Publications database. Values are given in g/kg and m/m^3 of fuel burned. The latter needed to be fixed so that it could be used in this analysis. Densities for the refined products had to be used to fix the units of the gas phase emissions results. Conversion factors between different units are common knowledge and can be found on the internet.

5. Preliminary Analysis

The supply elasticities calculated for the fuels are shown below

Table 1

Supply Elasticities

Elasticity of Supply - Residual	0.0003
Elasticity of Supply - Diesel	0.0027
Elasticity of Supply - Gasoline	0.3517

Note. These values are unit less.

The elasticities show that residual fuel is by far the most inelastic supply, followed by diesel (9x the elasticity for residual), followed by gasoline. Gasoline is the most elastic by a large degree, signaling that gasoline supply is sensitive to changes in price. Residual fuel is the least responsive to price, partly because this is a byproduct of refining a barrel of crude oil, and there are few uses outside of the bunker market. Bunker only accounts for 4-7% of global oil demand but, it is the largest sink for "bottom of the barrel" residual fuel (Halff et al., 2019). The market for bunker fuel is dominated by ocean going vessels, which account for 70% of bunker use. Demand shifting from bunker to diesel will have a much larger aggregate effect on the diesel market than the bunker market, because the price response will be much greater.

5.1 Residual Bunker Fuel

Figure 1

Equilibrium Points for Residual Fuel

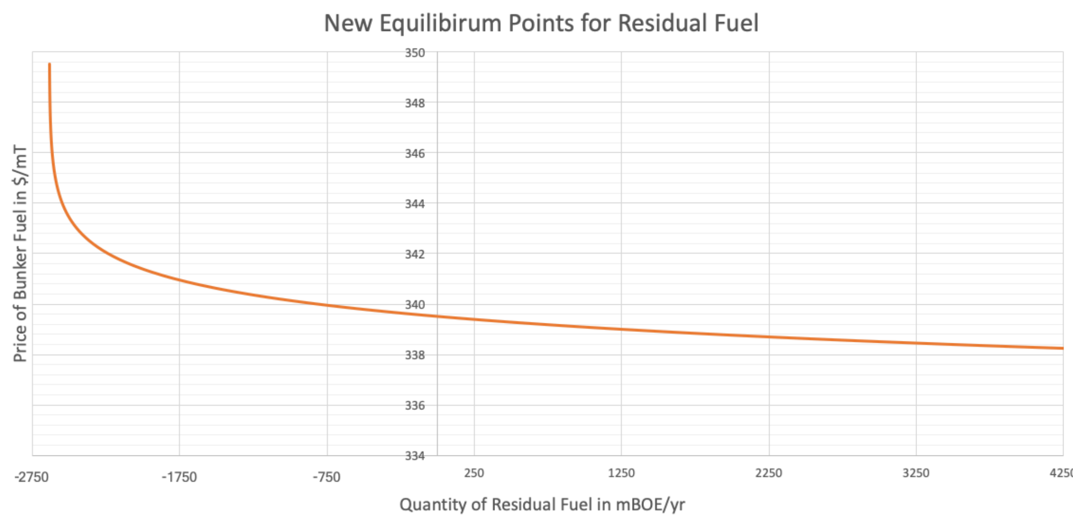
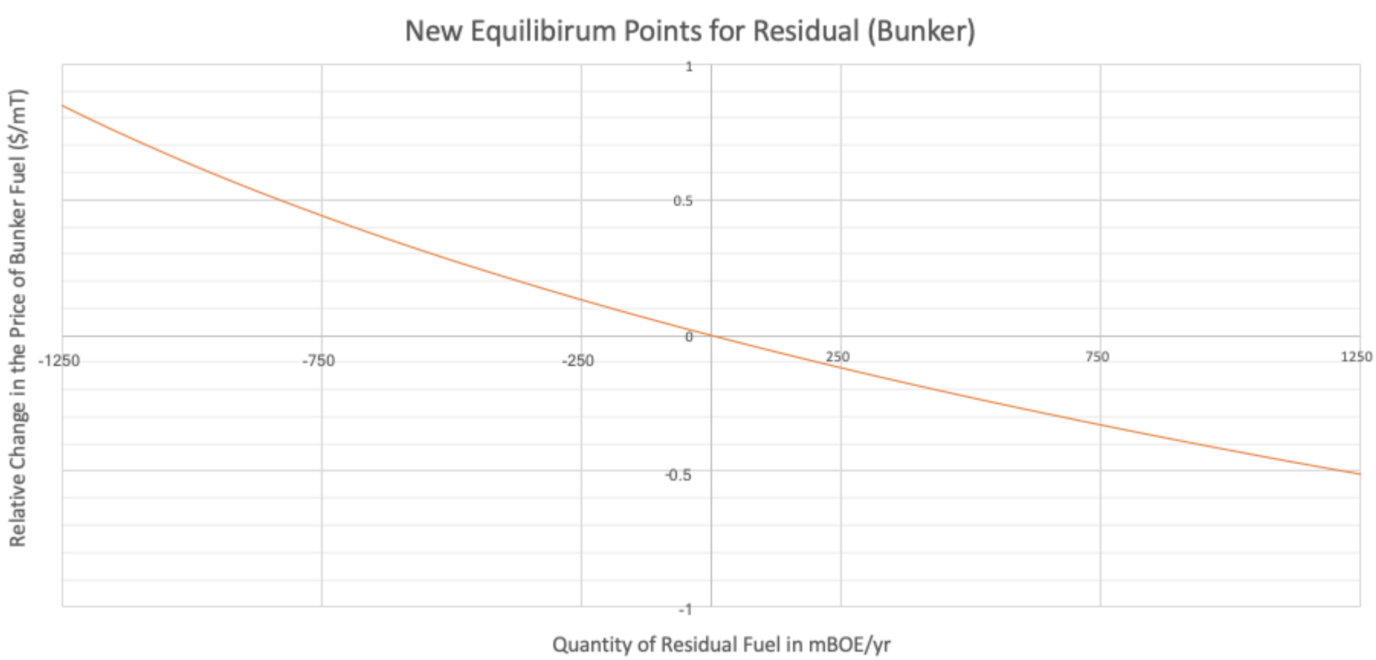


Figure 2

Equilibrium Points for Residual Fuel Near Origin



Note. This is a zoomed in version of figure 1 around the origin.

Residual fuel has an equilibrium curve that is not linear. It is important to note that this curve basically traces the new demand curve. This is an interesting find. At higher prices, the curve is nearly perfectly inelastic, as denoted by the vertical part on the left side. As price decreases, bunker fuel demand becomes more responsive to changes in price, nearing perfectly elastic, as it approaches a horizontal line. If the price of bunker fuel were to drop after January 1st, there could be a shift to using scrubbers, rather than an alternative refined product because the long-run cost could potentially be less.

Equations were estimated for how emissions would change based on a change in the quantity of a fuel demanded. The most obvious find, is that there is more CO_2 production than any other pollutant (it has the largest slope coefficient). This is followed by Particulate Matter 2.5 (PM2.5), which is a proxy for sulfur oxides. It can be seen that the ratio of reduction compared to nitrogen oxides and carbon monoxide is a factor of at least three time larger. Equations are given below in a table.

Table 2

Residual Fuel Pollutant Equations

Pollutant	Approximate Equation
CO	$y = 0.3695x + (3 * 10^{-10})$
CO_2	$y = 430.893x - (2 * 10^{-9})$
NO_x	$y = 17.06x + (3 * 10^{-9})$
SO_x (PM2.5 used as proxy)	$y = 78.186x + (1 * 10^{-8})$

Note. Values for pollutants are measured in metric tons.

There is a continuum of scenarios that could happen with the bunker demand reduction. I model three different scenarios, 50%, 75% and 100% reduction of the maritime bunker fuel market. The market sits at about 3.3mbpd, and percentages will be taken from this amount.

Table 3

Residual Market Size Change

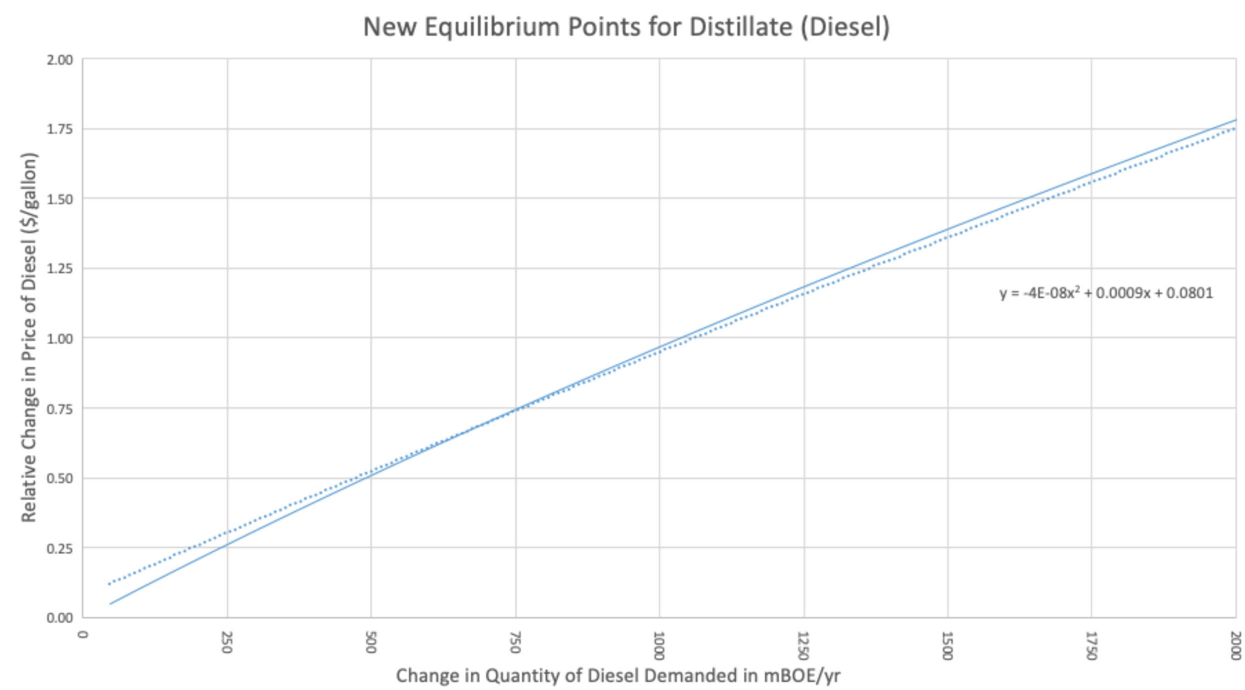
Scenario	Bunker Loss	Price Change ($/mT)	Size of Market Change (m$)
50% Bunker Reduction	1.7mbpd (620.5mbpy)	-0.27	-25.01
75% Bunker Reduction	2.5mbpd (912.5mbpy)	-0.41	-55.84
100% Bunker Reduction	3.3mbpd (1204.5mbpy)	-0.50	-89.85

Due to the nonlinear nature of the bunker equilibrium curve, the change in the size of the market is not linear. As more fuel is moved out of the market, the larger the effect will be, as the change between 50% and 75% is $30m and the difference between 75% and 100% is $34m.

5.2 Distillate Fuel Oil

Figure 3

Equilibrium Points for Distillate Fuel



The equilibrium curve for diesel is linear, but was best approximated by a quadratic trend line of order 2. The new equilibrium point curve for diesel traces out the supply curve for global diesel at relative shifts in prices. There are no radical shifts in this curve, compared to the equilibrium curve for residual fuels. The start price of diesel used in this analysis was $2.01/gallon.

CO_2 is the pollutant that is created the most, again followed by PM 2.5. However, increases in CO_2 are nearly ten times more than that of PM2.5. The ratio of pollutants (excluding CO_2) to SO_x is much lower, with a maximum of two.

Table 4

Distillate Fuel Pollutant Equations

Pollutant	Approximate Equation
CO	$y = 0.2903x + (6 * 10^{-13})$
CO_2	$y = 439.88x - (3 * 10^{-9})$
NO_x	$y = 15.665x - (1 * 10^{-10})$
SO_x (PM2.5 used as proxy)	$y = 33.885x - (8 * 10^{-11})$

Note. Values for pollutants are measured in metric tons.

Scenarios were again used to show some degree of a continuum in bunker reduction.

Table 5

Distillate Market Size Change

Scenario	Diesel Price Change ($/gallon)	Size of Market Change (b$)
50% Bunker Reduction	0.63	16.81
75% Bunker Reduction	0.90	35.31
100% Bunker Reduction	1.22	63.19

It can be seen that the diesel markets increase much more than the bunker markets lose. If all the bunker demand moved to diesel, that would increase the market by over $63 billion. Additionally, the changes in price are much more significant. Diesel is price in dollars per gallon, so a small change actually has a relatively large effect.

5.3 Pollutants

The most salient facts arise when analyzing both of these fuels together. The scenarios were used to show how much a reduction in bunker (picked up by diesel) would change the pollutant portfolio that is currently being emitted by large ocean vessels. Percentages in the table represent a change from the baseline of 100% bunker consumption.

Table 5

Changes in Pollutants

Scenario All Measurements in mT	**50% Bunker Reduction**	**75% Bunker Reduction**	**100% Bunker Reduction**
Change in CO (Bunker)	-229.27	-337.17	-445.06
Change in CO (Diesel)	180.13	264.90	349.67
Aggregate CO	**-4.67% (-49.14)**	**-6.87% (-72.27)**	**-9.08% (-95.39)**
Change in CO2 (Bunker)	-267,369.11	-393,189.86	-519,010.62
Change in CO2 (Diesel)	272,945.54	401,390.50	529,835.46
Aggregate CO2	**0.46% (5,676.43)**	**0.66% (8,200.64)**	**0.87% (10,824.84)**
Change in NOx (Bunker)	-10,585.73	-15,567.25	-20,548.77
Change in NOx (Diesel)	9,720.13	14,294.31	18,868.49
Aggregate NOx	**-1.77% (-865.60)**	**-2.60% (-1,272.94)**	**-3.43% (-1,680.28)**
Change in PM2.5 (Bunker)	-48,514.41	-71,344.73	-94,175.04

Change in PM2.5 (Diesel)	21,025.64	30,920.06	40,814.48
Aggregate PM2.5	**-14.13%** **(-27,488.77)**	**-20.78%** **(-40,424.67)**	**-27.43%** **(-53,360.56)**

Note. Percentages in the table correspond to a change from a baseline of 100% bunker use.

There are significant effects when looking at the changes in pollutants for both types of fuels. PM2.5, which is a proxy for sulfur oxides, will decrease the most, by over a quarter for the 100% reduction scenario. This is followed by CO, which reduces this particular emission by under 10%. NO_x, decreased very little, with every scenario having less than a 4% reduction in NO_x polluted. The change in the main greenhouse gas, CO_2, is quite minimal compared to the other pollutants except that it actually increases in every scenario since diesel produces more CO_2 than bunker fuel. The increase in every scenario is negligible, less than 1%. This can allude that CO_2 emissions from transferring to a low sulfur fuel, does not really have an impact on CO_2. The small increase in CO_2 is outweighed by significant reductions in the other criteria pollutants.

6. Discussion

The results show a significant change in both the residual and distillate markets. Residual demand is going to collapse come January 1st, 2020, and the demand will most likely shift to a diesel distillate to comply with the low sulfur regulation. There are factors that can change how the aggregate effect of this regulation plays out. First, the ratio of exchange between the two fuels will not be 1:1, but rather a fraction since the fuels have differing energy content. A barrel of bunker fuel has a little over 8% more energy content than a barrel of diesel. Although the analysis was done in barrel of oil equivalent which accounts for differing energy content, this is important to note because there is not going to be an even ratio, especially since different refineries have different margins (albeit little) between their refined products.

The relative changes between bunker and diesel are vastly different. Bunker fuel is priced by the metric ton and diesel is priced by the gallon. There was a much more significant increase in the price of diesel relative to the overall price, nearing and going over 50%. The change in price for bunker however, is less than 1% at the maximum scenario. This could be why the changes in each market are vastly different; diesel gains billions and bunker loses millions.

6.1 Implications on Markets

The two fuel markets have relatively opposite effects in the magnitude of the change. Since residual fuel is made regardless of if it is desired, there is going to go a large amount of unused residual fuel. Further, more diesel may have to be refined, which would take more crude oil, which would create more bunker fuel, with nowhere to go. The refineries that have a higher distillate refinement ratio and lower residual refinement ratio are going to benefit from this regulation, since they are already more geared towards creating low sulfur products. Additionally, there is going to be a premium put on crude oil that is low in sulfur, such as West Texas Intermediate (WTI) and North Brent, which will benefit those regions because of the increase in demand. Regions that have higher sulfur content in their crude oil are going to see a decrease in demand, because most of the residual market is disintegrating. Refineries that also have poorer ratios of refinement, respectively, will find themselves in a tough situation where they may need to shut down, because the profit margins are no longer viable to maintaining a business.

It is likely that scrubbers will become a common form of compliance by ocean going vessels once IMO 2020 is in effect. This would allow companies to continue to use bunker fuel in place of a cleaner alternative. There will however, be some transfer of demand to diesel, so the price of bunker fuel is going to decrease. If the price of the fuel decreases enough, it is going to encourage the use of scrubbers instead of switching to a different fuel, which in the long term will not reach goals set out by the IMO. Scrubbers, while although compliant with IMO, are a workaround for businesses to save money. Most scrubbers installed are open-loop, which means that they return the water they use to scrub the emissions back into the ocean. The ratio of a ton of emissions to seawater (in tons) is 4-5, meaning that there is equal if not more significant pollution occurring form the use of scrubbers (Crisp 2019). Regulations on the type of scrubbers used need to be put in place, and some countries have already moved forward to state that open loop scrubbers will not be tolerated along their coastlines. Over $12 billion dollars has already been invested in scrubbers, with less than 1% of those scrubbers closed loop (Crisp 2019). The companies will be meeting the regulation, but at the cost of the other major ecosystem, the ocean.

6.2 Implications on the Environment and Public Health

The effect of pollution from ships is compelling. The goal of this regulation is to reduce the number of atmospheric SO_x, and this regulation does just that. There is over a 50% reduction in PM2.5 for every scenario. For people living near major shipping lanes and the coastline, this is a major improvement in the air that they breathe daily. There should be a reduction in the amount and intensity of asthma, lung cancer and pulmonary disease following the implementation of IMO 2020 after a couple of years. Stroke and cardiovascular disease are also linked to poor air quality, specifically for PM2.5, so there should also be a reduction in these conditions near coastlines. Additionally, since SO_x is the direct contributor to acid rain, there should be less acidic rain everywhere. This will help with species security on land and in water. Oceans will acidify less quickly, and forests and aquatic species will have a greater chance at survival without being bombarded by acidic rain. Further, the effect on agriculture will be the most significant near the coastlines. By decreasing the amount of acid rain, there is a lower likelihood of crop failure, which is extremely helpful in countries that do not have a crop insurance system and communities that are lower on the socioeconomic spectrum.

There is an issue with the reductions in emissions however. Most of the pollutants are being emitted over the open oceans, not near coastlines. Many countries have emission control zones that stretch out to ten miles from their coastline. These zones limit what fuel these vessels can use, what speed they are allowed to move at and how much they can pollute. Although there is a major reduction in pollution, it will most likely be an aggregate effect around the world due to the nature of the atmosphere. It may be hard to gauge the direct effect that the reduction in pollution from the maritime sector may have on the rest of the world, since it would be near impossible to model where these pollutants end up, once they are emitted out on the ocean.

7. Post Implementation Analysis

There were large challenges with analyzing the effect of this regulation in the short term. There are many confounding factors that make it nearly impossible to single out any effect that the regulation had on the markets or the environment.

7.1 Model

The model used for analysis after IMO 2020 was implemented is relatively simple. It consists of gathering price, demand and supply data for residual and distillate fuel. This will focus on the impact of the regulation on markets. Using consumption data on the fuels, the impact on the environment can be investigated.

7.2 Predictions

From the preliminary analysis, multiple economic and environmental shifts were predicted. Three scenarios were used to show a general scale of what would happen: 50%, 75% and 100% reduction in bunker fuel use. The slack from the bunker market was predicted to be picked up by the diesel market. Therefore, a 50% reduction in bunker demand represents a 50% increase in diesel demand, roughly.

As more bunker fuel is taken away from the bunker market, there is a more significant effect on the price of the fuel. In the scenario with a 50% bunker demand, there would be a loss of 1.7mbpd and the price would decrease $0.27/mt. For a 75% reduction, a 2.5mbpd loss and a price drop of $0.40/mt. For a 100% reduction, a 3.3mbpd loss and a $0.50 decrease in price. The price is not extremely high at a 100% reduction because while demand may not be there, there is still going to be residual fuel produced as a byproduct of refining crude oil.

With this demand reduction in bunker shifting to diesel, the diesel market makes considerable gains. With a 50% reduction in bunker demand, the price of diesel increases by $0.63/gallon. For a 75% reduction, the price increases $0.90/gallon. For a 100% reduction, the price increases by $1.22/gallon. Notice the scale difference. The price of diesel is per gallon and the price of bunker is per metric ton. There is a larger price change for a smaller scale in terms of diesel.

The effect on the environment from switching away from residual fuel is great. There is a reduction in every pollutant except CO_2. NO_x had the smallest reductions, usually hovering right below 10%. CO had reductions that were nearly 25%. The most profound results of this preliminary analysis is the effect on particulate matter; there is at least a 50% reduction in particulate matter across all scenarios. CO_2 was the only pollutant that increased its amount in the environment from the policy change. The increase however, was only around 2%.

8. Effect of Current Events

8.1 Russian-Saudi Oil Price War

After about two months into 2020, an oil price war arose between the Russians and the Saudis. This had a very profound effect and deepened the economic hardships that the novel Coronavirus has created. Due to a decrease in demand from Coronavirus, global production had to slow down so that the price of oil would not collapse. On March 5th,

> "OPEC has agreed to impose a deeper round of production cuts in order to support oil prices…the 14-member group, led by Saudi Arabia, decided on Thursday to cut production by 1.5mbpd through the second quarter of the year…the cuts are believed to be conditional upon approval from Russia" (Meredith & Ellyatt, 2020).

The following day, "Russia rejected and oil prices fell 10%" (BBC News, 2020). This was the beginning of the price war. OPEC had decided that production cuts were necessary and called on the members of OPEC+ (OPEC plus some non-OPEC countries, like Russia) to follow their lead. Russia is notorious for not wanting to cut crude production because of how important it is to their economy. Following the response from Russia, “on 3/8/20, Saudi Arabia announced price discounts of $6-$8 per barrel to customers in Europe, Asia and the United States. This triggered a free fall in oil prices. Brent crude fell 30%, the largest drop since the Gulf War” (Perper, 2020). Beyond supply contraction, there is major demand contraction.

> “The International Energy Agency dramatically revised its oil demand forecast, predicting consumption will actually contract by 435,000 bpd, the first outright decline year-on-year since the global financial crisis…previously, the agency expected consumption to increase by 800,000bpd from a year earlier” (Cunningham, 2020).

On March 9th, following what has happened between the Russians and the Saudis, “stock markets crashed. Dow Jones Industrial fell over 2,000 points or 7.8%, becoming the largest point drop in history” (Bayly, 2020). Over the course of less than a week, these two countries collapsed the price of oil and made it much harder for countries that rely heavily on oil production to bring themselves out of this hole. This situation affects the United States because they are the number one producer and top five exporter of oil. Lower prices in other oil producing countries means that there are alternatives of the same fuel that firms can buy. While the U.S. did not participate in this price war, its affect is seen on the them and the rest of the world.

8.2 Coronavirus

The Coronavirus pandemic has created a tremendous amount of uncertainty about markets and economies as a whole. We are currently in a “deep global recession” (Fitch Ratings, 2020) because of the major loss in consumption throughout the world. “Nationwide lockdowns are reducing daily activity by about 20% from normal levels” (Fitch Ratings, 2020). Situations around Coronavirus have caused the WTI benchmark in the United States to actually go negative in price, the first time ever recorded. The effects of Coronavirus are widespread and dominates any impact that the IMO regulation may have had.

Modern economies rely very heavily on consumption as a major component of GDP. This will cause GDPs across the globe to contract this year. Fitch Ratings has been on top of analyzing the situation. Their chief economist, Brian Coulton, stated “our baseline forecast does not see GDP reverting to is pre-virus levels until late 2021 in the U.S. and Europe” (Fitch Ratings, 2020). This is an optimistic look for the U.S. and Europe, but there are other countries that are much more affected from this pandemic. “Advanced economies were generally in better shape to deal with the crisis, but many emerging markets and low-income countries face significant challenges, including outward capital flows” (Shalal & Lawder, 2020). A hard truth about this pandemic is that wealthier countries are going to be able to rebound from this much quicker than other developing economies. A good comparison is to the financial crisis. Wealthier countries were able to provide stimulus packages and other economic incentives to pull the economy out of the rut. Developing countries do not have that luxury; it took them considerably longer than the wealthier countries to recover. It seems like this situation is going to happen again, maybe even greater in magnitude. The duration of how long services are shut down for the Coronavirus, directly impacts the damage that it is going to do to the economy. The longer the shut downs continue, the deeper the global recession is going to be.

8.3 Following Collapse in Baltic Dry Index (BDI)

The Baltic Dry Index is used as a gauge for the price of transporting raw bulk commodities by sea. It takes into account twenty-three different trade routes that carry many different types of commodities. In 2020, there has been a collapse in this index, due to a lower cost of oil and the momentous loss in consumption around the world. Less raw materials and goods are being transported and the price of bunker fuel has collapsed, so it is much cheaper to transport materials now rather than before 2020. On January 2nd, the BDI was at 1090.00 but by April 3rd, the BDI was 616.00. This was not the low point. BDI bottomed out at 411.00 on February 10th.

8.4 Summary Consequences of 2020

These effects bleed into each other. It started with the Coronavirus, which fed the oil price war, which fed back into the economic effects of Coronavirus. My analysis was going to focus on consumption, production and the prices of crude oil and some refined products. This is nearly impossible now because of these confounding factors; there is no way to remove the current events to solely analyze the effect of IMO 2020. Further, these events were a major shock to the shipping industry. Their implementation plans for IMO 2020 may have now changed given the circumstances. The price of bunker fuel is relatively inexpensive now, so shipping companies could continue to use bunker fuel and install scrubbers. Ultimately, the capital cost of the scrubbers is going to offset how much they pay in fuel, because of the low price. The BDI is going to take some time to recover. The price of shipping is dependent on consumption activity around the world. Until this consumption returns to normal levels, it would be reasonable to think that the index will not return to normal levels. The duration of the Coronavirus is also an important factor. The longer that this pandemic continues on for, the longer that these shipping businesses are going to be operating in the red. At this point, it becomes a battle of attrition; who can survive the others? These current events seriously affected every industry, but the shipping industry has to be one that has been the most affected. If the Coronavirus continues and the price of oil remains low, the shipping industry could be in some serious trouble.

9. Conclusions

There are two key things to regulations: they have to think about all of the ways that firms will try and comply and that the process of creating a regulation and then implementing it is very time and cost intensive. For the first point, the idea behind IMO 2020 was well intentioned. The issue however, is that they only regulated the sulfur content in fuels. This could either be done through switching to a cleaner fuel or installing scrubbers. What the regulators did not consider, was if these companies use scrubbers, then they have a choice between different types of scrubbers. The cheap and popular one is an open-loop, where seawater is used to clean exhaust of sulfur, but then that very acidic seawater (with other pollutants from cleaning the exhaust) is let back into the ocean. For every ton of exhaust, anywhere from two to five tons of seawater is needed. This circumvents the regulation. The shipping companies are just installing these scrubbers and then continuing to use the dirtiest fuel possible. Not only that, but they are polluting the ocean rather than the air. Countries now have to take it upon themselves to set up rules for the types of scrubbers allowed in their waters, but this should have been included in the regulation. They are just moving the sulfur around, not getting rid of it.

IMO 2020 took over 20 years to prepare, with interdisciplinary collaboration from around the world. While cost was not discussed, it is relatively easy to imagine how expensive setting up a regulation like this can be. One of the failures of IMO 2020 is that it took over 20 years of hard work to set up. In the end, it basically did not matter because the companies are still using bunker fuel and installing scrubbers that put the pollutants into the ocean.

IMO came out strong with a regulation focused on large ocean going vessels using cleaner fuels. This had and will have an effect on markets and the environment. It was suspected that there would be some percentage of bunker demand shifted to diesel fuels, which would contract the bunker market but expand the diesel market. Taking a reduction in bunker and applying it fully to the diesel market, the environment would see many gains except for CO_2. The issue however, is that there are current events that create confounding factors for the analysis after the regulation went into effect. Two major events are happening in the world: Coronavirus and an oil price war. Both of these affects decreased global aggregate demand for oil, which collapsed the price of oil. The price of shipping collapsed because of a lack of consumption. The effects on the markets were profound, and it would be nearly impossible to try and remove these events from the data.

The price of shipping is not going to rebound until economies are acting normal again. This could be in late 2021, in which case, could be very detrimental for the shipping industry. Most companies, in particular shipping companies, use their current data to plan for the future. The issue however, is that these companies have been buying new ships with new technology that are extremely expensive. They do not have the capability of deciding that they no longer desire the ships because these vessels are built under contract. Since there is a lack of demand for shipping right now, they will probably have to minimize operations by reducing the number of ships on the ocean at any going time. These newer ships might not be able to be used for years, for which the shipping company have to pay for maintenance. Sooner or later, economies and markets around the world will return to normal, but it is the speed at which this is done that matters. There could be significant effects on the industry that they might not be able to come back from as easy as people believe, such as structural friction when hiring back a large proportion of their employees. The longer these events continue on, the more severe the effects are going to be on the shipping industry, all other industries and the rest of the world. This is an unprecedented time, and an incredible case study for economics.

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