$200 Crude, the Economic Crisis of 2020, and Policies to Prevent Catastrophe

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The great American philosopher, scientist, and statesman Benjamin Franklin included a version of a famous proverb in *Poor Richards Almanack*, published in 1758. It begins "for want of a nail" and ends by warning that a kingdom was lost "all for want of a horseshoe nail." The proverb dates to 1230. As Wikipedia explains, the aphorism warns of the importance of logistics, of having sufficient supplies of critical materials.[1]

The global economy likely faces an economic crash of horrible proportions in 2020, not for want of a nail but want of low-sulfur diesel fuel. The lack of adequate supplies promises to send the price of this fuel—which is critical to the world's agricultural, trucking, railroad, and shipping industries—to astoundingly high levels. Economic activity will slow and, in some places, grind to a halt. Food costs will climb as farmers, unable to pay for fuel, reduce plantings. Deliveries of goods and materials to factories and stores will slow or stop. Vehicle sales will plummet, especially those of gas-guzzling sport utility vehicles (SUVs). One or more major US automakers will face bankruptcy, even closure. Housing foreclosures will surge in the United States, Europe, and other parts of the world. Millions will join the ranks of the unemployed as they did in 2008.

All for the want of low-sulfur diesel fuel or gasoil.

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[1] See "For want of a nail," Wikipedia [https://tinyurl.com/n7sb629].

The cause of the coming economic collapse is an obscure agency created in 1914, two years after the *RMS Titanic* sank. Now called the International Maritime Organization (IMO) and operated under the United Nations' auspices, this body regulates many activities associated with global shipping, including marine fuel quality. In 2016, the IMO, whose members include most UN countries, decreed that oceangoing ships must adopt measures to limit sulfur emissions or burn fuels containing less than 0.5 sulfur—in other words, switch to low-sulfur diesel fuel. The sulfur rule takes effect January 1, 2020, just months from now.

The economic collapse I predict will occur because the world's petroleum industry lacks the capacity needed to supply additional low-sulfur fuel to the shipping industry while meeting the requirements of existing customers such as farmers, truckers, railroads, and heavy equipment operators. These users purchase diesel fuel or gasoil, the petroleum product that accounts for the largest share of products consumed. In most countries, they must buy low-sulfur diesel fuel to reduce pollution. Quite simply, low-sulfur diesel fuel or gasoil is the nail essential for twenty-first-century economies, governments, and militaries to function.

Gasoil and low-sulfur diesel prices must rise significantly when the IMO 2020 rule takes effect. On this, there is no disagreement. Economists at the International Energy Agency, the intergovernmental body "founded in 1974 to help countries collectively respond to oil supply disruptions," have warned that these prices must increase twenty to thirty percent. Analysts at various consulting firms and investment banks have produced similar estimates.

While higher prices are worrisome, they should not by themselves lead to a major recession. After all, diesel fuel prices have increased more than thirty percent at various times this decade. However, these estimates assume that crude prices do not change. Indeed, the authors of a crucial IEA report, *Oil 2018*, specifically make this assumption.[2]

Difficulties will arise because crude oil is not a homogeneous commodity like, for example, bottles of Jack Daniels Kentucky sour mash. Instead, crude oils vary regarding their qualities and composition, and these differences exceed those of most other goods. Worldwide, perhaps only one other commodity is as diverse: wine. For the latter, one can speak of whites, reds, rosés, or sparkling wines, and each of these categories is subdivided even further. The volumes fermented by any given vintner can range from a few cases to thousands of cases. Prices range from less than a dollar per bottle to thousands. Crude oil is the same as wine regarding variety and production volumes, but the price range is narrower.

Two important distinguishing factors among crude oils are how much sulfur they contain and the diesel fuel volume they produce when refined. Some crude oils—the light sweet varieties—contain minimal sulfur and produce large amounts of low-sulfur diesel. A far greater number—the heavy sour crudes—contain a higher percentage of sulfur and do not produce diesel that meets environmental sulfur-content standards without expensive additional processing. The diesel fuel produced from Nigeria's best crude oil has a sulfur content of 0.13 percent when refined, while the diesel refined from Middle East light crude oil, one of the most common crudes, contains 0.53 percent.

While many world refineries can produce low-sulfur diesel fuel from heavy sour crudes, a large number have not been equipped to do this yet and thus cannot help in meeting the IMO 2020 requirements. For

[2] See IEA, *Oil 2018: Analysis and Forecasts to 2018*, March 2018 [https://tinyurl.com/yamodjhq].

example, much of the incremental crude that will be supplied in 2019 as world production increases will be Arab Heavy. The distillate produced from this crude contains between 1.8 and two percent sulfur.

The marine-fuel quality requirement being imposed on the maritime industry represents the last step in a long progression to remove sulfur from petroleum products. Over the last two decades, most nations' governments have taken significant steps to force sulfur removal from these products. The most important, most notable changes have occurred with diesel fuel. Diesel-powered vehicles once spewed heavy black smoke. Today, with the mandated low-sulfur fuel, that harmful pollution has mostly vanished.

Much of the sulfur in crude is not removed during refining but rather ends up in "fuel oil," the "dregs" or residue left over after all the high-value products have been distilled out. It is the cheapest liquid fuel available. It is also viscous (it must be heated before use) and contains many pollutants, particularly sulfur, that are harmful to humans, animals, and plants.

Since the turn of the twenty-first century, most fuel oil has been consumed by the shipping industry due to the environmental restrictions on other uses. It was only a matter of time before those restrictions came to marine fuel. According to a *Nature* article cited by Goldman Sachs, sulfur dioxide pollution from fuel-oil-burning ships is a contributing factor in approximately four hundred thousand deaths from lung cancer and cardiovascular diseases and fourteen million childhood asthma cases every year.[3] Environmentalists have pushed for sulfur removal from marine fuels because sulfur dioxide has been linked to a wide array of illnesses.

[3] Nikhil Bhandari et al., "The IMO 2020: Global Shipping's Blue-Sky Moment," Goldman Sachs, May 30, 2018, p. 7.

The public-health arguments for the IMO 2020 rule are uncontestable and compelling. The IMO's approach to reducing pollution, however, is questionable. The financial consequences of allowing ships to burn fuel with 3.5-percent sulfur until December 31, 2019, and then ordering them to switch to fuel containing 0.5-percent sulfur on January 1, 2020, could be high for the oil industry and the world's economies.

The IMO 2020 rule will force a major change on refiners. As I discuss below, the shipping industry has passed the compliance burden to the oil industry, that is, shippers expect refiners to produce the low-sulfur marine fuel they will need beginning in 2020. For this to happen, refiners will have to boost production of low-sulfur gasoil and fuel oil, according to most studies, by around two million barrels per day.

Table 1 shows the required shift as reported by the IEA. The added gasoil and low-sulfur fuel oil demand shown there represents a seven-percent rise in diesel production from 2019 to 2020 **in addition to the three-percent increase required for other purposes such as vehicle use.** This entire increase will need to contain little sulfur. It is not clear that the greater volumes can be produced. Instead, as noted below, very large price hikes may be required to suppress non-maritime use.

Table 1. Bunker Deliveries in OECD and Main Non-OECD Countries (Thousand Barrels per Day)

	2016	2017	2018	2019	2020
Marine Gasoil	728	745	756	767	1,736
Very-Low-Sulfur Fuel Oil	0	0	0	0	969
High-Sulfur Fuel Oil	3,049	3,126	3,018	3,231	1,292
Total	3,778	3,872	3,872	3,997	4,017

Source: IEA *Oil 2018*.

At the same time, refiners will need to "destroy" or find new markets for up to two million barrels per day of high-sulfur fuel oil. Some of it will be sold to oil-burning powerplants such as those in the Middle East. These plants could and likely will shift to residual fuel oil to save money. High-sulfur fuel oil prices are projected to fall dramatically as the IMO 2020 mandate approaches and takes effect. Ironically, the maritime fuel switch may do nothing to improve the global commons given that the pollution sources can just be moved from the high seas to land.

Other volumes of high-sulfur fuel oil will be sold to refiners configured with cokers, where they will be "destroyed," to use the oil industry's language. Cokers split heavy fuel or heavy crude into light products and coke. ExxonMobil's new coker at its Antwerp refinery, for example, will "turn high sulfur oils created as a byproduct of the refining process into various types of diesel, including shipping fuels that will meet new environmental laws."[4] These units will be critical in converting fuel that can no longer be burned in ships into marketable products. The rub is that cokers are very expensive (ExxonMobil's will cost more than $1 billion) and require significant construction time.

ExxonMobil is also considering additional investment in its Singapore refinery to produce diesel fuel that satisfies the IMO 0.5-percent cap. It will be of no use in 2020, though, because the final investment decision will not be made until 2019, and, if the project goes forward, the facility will not be ready before 2022, two years after the IMO rule becomes effective.[5]

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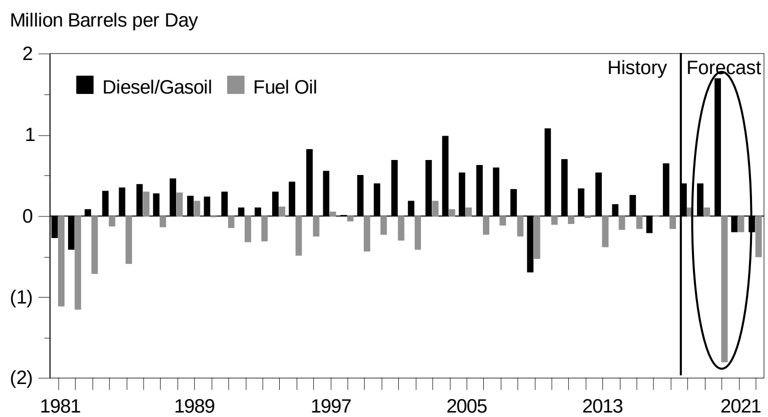
[4] "Exxon defies downturn with $1 billion Antwerp refinery investment," Reuters, July 2, 2014 [https://tinyurl.com/yaf48c4u].
[5] Esther Ng, "ExxonMobil proposes Singapore facility upgrade to produce 0.5% sulfur fuel," S&P Global Platts, June 27, 2018 [https://tinyurl.com/ydhsm9l5].

The magnitude of the coming oil market transformation is unprecedented. Figure 1 shows the year-to-year change in diesel fuel and heavy fuel oil supply from 1981 to 2017 and as projected to 2022 by the IEA. It is this historic increase in demand for low-sulfur diesel combined with the equally historic need to dispose of unwanted fuel oil that will, absent moderating actions by nations and the IMO, cause an economic collapse in 2020.

Figure 1
Year-Over-Year Change in Global Diesel/Gasoil and Fuel Oil Consumption, 1981 to 2017 and Projected to 2022



Source: BP Statistical Review of World Energy; IEA.

If nothing changes, the 2020 diesel and gasoil crisis will occur because as many as half of world refineries cannot produce fuel that meets the new regulation. These “simple” facilities produce significant volumes of high-sulfur fuel oil. The mix of products produced from such refineries is dictated by the type of crude processed. They can produce low-sulfur diesel if the crude inputted to the refinery contains little sulfur (as, for example, Nigerian crudes do). They cannot reprocess a high-sulfur diesel fuel to a low-sulfur diesel because their facilities are inflexible. The owners of these units will face harsh choices.

First, they could close. Many will have to shut down, and these closures will reduce the volume of petroleum products available to the market, sending prices higher.

Second, they could find an alternative market for the high-sulfur fuel oil. As noted, refineries with cokers might take the fuel oil, especially if it sells for next to nothing. Today, the high-sulfur fuel oil price is roughly ninety percent of the crude price. In 2020, it could fall as low as ten percent of the crude price. As a result, the price of low-sulfur distillate, which today sells for one hundred twenty percent of the crude price, would need to rise to perhaps two hundred percent of the crude price to compensate the owners of refineries with limited flexibility that can produce some low-sulfur diesel along with equal or larger volumes of high-sulfur fuel oil. Should prices of low-sulfur distillate fail to rise to such levels, these facilities will have to close.

Third, the owners of simple refineries could attempt to procure a different crude feedstock. The only way for these refineries to vary their output is by changing the crude processed. Some crude oils, as mentioned, produce more low-sulfur diesel and less high-sulfur fuel oil than others. Operators of simple refineries, in theory, could survive the IMO 2020 transition by changing the crude oil they process to "light sweet" crudes that can yield high volumes of low-sulfur distillate, crudes such as those from Nigeria.[6]

There is, though, a market constraint to the third option. Volumes of low-sulfur crude oil are limited, and supplies are less certain because these crudes are produced primarily in Nigeria, a country that suffers frequent, politically induced market disruptions. Thus, when the inflexible refiners begin bidding for Nigerian oil, prices will rise, perhaps as much as three or four-fold.

[6] Major refiners acknowledged to the International Energy Agency that this would be a key part of their strategy in satisfying the IMO regulation. See IEA, *Oil 2018* [https://tinyurl.com/yamodjhq]. p. 96.

The experience of the last decade vividly illustrates what will likely happen in 2019 and 2020. From 2006 to 2008, crude prices rose almost three-fold, peaking at $140 per barrel. The Great Recession, the worst global economic downturn since the Great Depression, followed. While economists do not agree on how much high oil prices contributed to the Great Recession—most point to the housing bubble's collapse as the primary cause—they do view oil prices as a factor.

Much of petroleum's contribution occurred before the Lehman Brothers failure in 2008, the event that many believe was the Great Recession's principal cause. However, the recession was inevitable at that time. Economist James Hamilton asserts strongly, for instance, that the oil price increase in 2008 would have caused a recession on its own.[7] The price rise had already exacerbated a significant downturn in the US automobile industry. General Motors, Ford, and Chrysler had begun closing plants and laying off workers early in the year as sales of SUVs and many autos all but stopped due to lack of demand.

IEA economists explained at the time that the oil price rise from 2007 to 2008 resulted in part from the frenzied bidding for limited quantities of low-sulfur crude oil, especially supplies from Nigeria. Then, as today, many refineries could not manufacture low-sulfur diesel from other crude-oil types, such as the Middle East's light crude oils, because they lacked the needed equipment. In 2008, such refiners contentiously bid for low-sulfur crude, driving prices higher as they sought to avoid closure.

This inability to process higher-sulfur crude oils created a peculiar situation. Ships loaded with such crudes were stranded on the high seas because the cargo owners could not find buyers. At the same

[7] James D. Hamilton, "Causes and Consequences of the Oil Shock of 2007-08," *Brookings Papers on Economic Activity*, Spring 2009 [https://tinyurl.com/ya92fs7c], pp. 214-294.

time, prices for light sweet crudes rose to record levels. The desperate need for low-sulfur crudes caused buyers to bid their prices higher and higher.

This situation will reoccur in 2020. The global refining industry will not be able to produce the additional volumes of low-sulfur diesel and low-sulfur fuel oil required by the maritime industry. In some cases, refiners will close because they cannot find buyers for the high-sulfur fuel they had sold as ship bunkers. In others, refiners will seek lighter, low-sulfur crude oils, bidding up prices as they did in 2008. This price increase may be double the 2008 rise, however, because the magnitude of the fuel shift is greater and the refining industry is less prepared.

The crude price rise will send all product prices higher. Diesel prices will lead, but gasoline and jet fuel will follow. US consumers could pay as much as $6 per gallon for gasoline and $8 or $9 per gallon for diesel fuel. I offer details backing this cataclysmic view below.

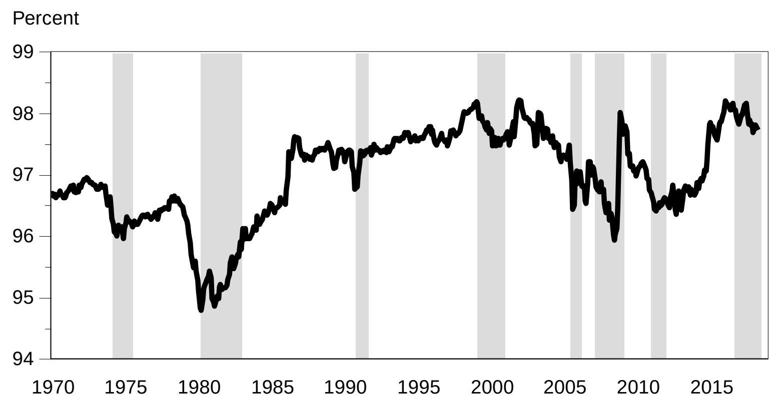
The high petroleum product prices will have two impacts. First, prices of everything consumed in the economy will rise. Second, high prices will force consumers to spend less on other goods and services, which will depress demand for airline travel, restaurant dinners, and new automobiles, to mention just a few.

The potential impact of higher fuel prices on everything purchased across the economy is obvious. They will raise costs in the agricultural sector, leading to higher food prices. They will boost delivery costs and airline ticket prices. The potential effect on individual consumers is subtler than the effect on industries. The price elasticity of demand for fuels is very low, less than 0.1 according to most estimates. This elasticity translates to consumers cutting fuel use by one percent when prices increase ten percent. Put another way, a ten-percent increase in gasoline or diesel prices would force consumers to spend nine percent more on fuel.

Consumers can offset this incremental nine percent in two ways. First, they can save less, assuming they can save at all. Alternatively, they can cut other expenditures. The data on consumer spending habits reveal that most incremental funds spent on fuel come from reduced expenditures on other items. I have studied eighteen past episodes of oil price disruptions in the United States. In every instance, consumers spent less on other items. The reductions have ranged from 0.5 to one percent of their total spending.

Figure 2 traces consumer spending by month from 1970 to the present. Here the data show the share of consumer budgets not spent on motor fuels. The shaded areas mark the periods of major oil market disruptions and large price increases. One can observe that the share spent on items other than energy dropped on each occasion. The total amount spent on items other than energy fell as well.

Figure 2
Share of US Consumer Spending NOT Allocated to Energy, 1970 to 2018, with Market Disruption Periods Marked

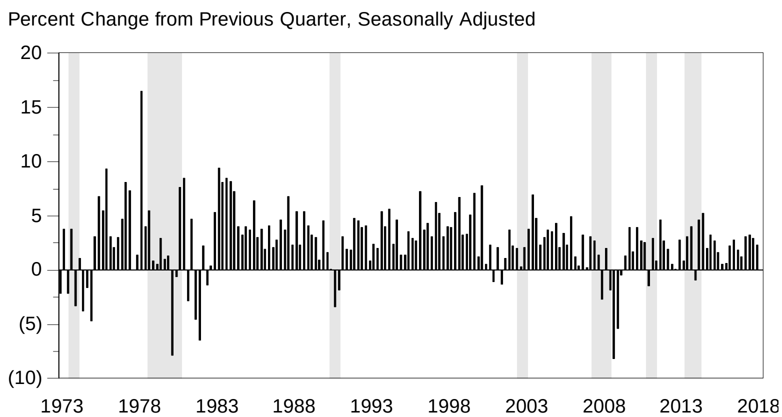


Note: Shading indicates a market distruption.
Source: PKVerleger LLC.

These reductions are spread across many activities, hitting every sector. Restaurants will see lower sales, auto dealers will sell fewer cars, auto manufacturers will produce fewer cars, hotels will welcome fewer guests, and airlines will carry fewer passengers. In every instance, employment in these industries declines. Those losing jobs must consume less, multiplying the impact of higher fuel prices.

Looking back over the last forty-five years, one can measure the effect of disruptions. The hard evidence for the harm they cause is presented in Figure 3. This graph shows the percentage change in real US GDP from the prior quarter from 1973 through the first quarter of 2018. The shaded areas highlight the quarters in which oil markets were disrupted. This timespan saw one hundred fifty-three undisrupted quarters and twenty-eight disrupted quarters. The average growth rate in undisrupted quarters was three percent at annual rates, while average growth in disrupted quarters was 0.8 percent. The difference strongly suggests a link between oil price disruptions and US economic growth, if not global growth.

Figure 3
US Real GDP Changes from Previous Quarter with Oil Market Disruptions Marked, 1973 to 2018

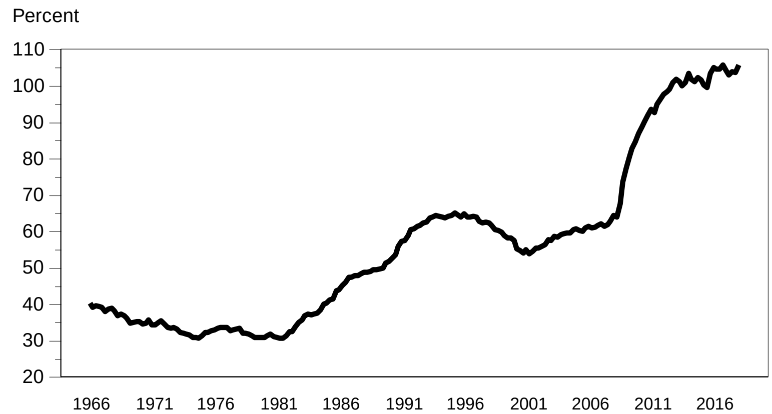


Source: PKVerleger LLC.

I fear the four quarters of 2020 and possibly 2021 will be shaded when I update the graph in three years. Sadly, the economic losses could be much greater than any experienced in the prior five decades.

The US economy will be further handicapped by the federal government's debt. The ratio of US debt to GDP has increased from sixty percent in 2008 to one hundred three percent today as can be seen from Figure 4. The increase in debt, combined with the tax cuts enacted in 2017, leaves the country with little room to address a recession. Instead, a large oil price increase could lead to an extraordinarily difficult downturn. The federal government might find it impossible to fund an infrastructure program. Many states might be unable to provide income supplements to the unemployed.

Figure 4
Total US Public Debt as Percentage of GDP, Quarterly Data, Seasonally Adjusted, 1966 to 2018



Source: Federal Reserve Bank of St. Louis.

Emerging market nations would suffer as well. These nations would be especially exposed because they already face significant economic weakness as a strengthening dollar and rising US interest rates cause large declines in bond and equity markets in countries such as Brazil and Turkey. Harvard professor Kenneth Rogoff, coauthor of *This Time is Different* with Carmen Reinhart, has warned that "rising global real interest rates are the number one predictor of financial problems in vulnerable economies," adding "the risks are greater than people realize."[8]

[8] Ira Iosebashvili, Ben Eisen, and Amrith Ramkumar, "Emerging-Markets Rout Boosts Contagion Fears," *The Wall Street Journal*, June 10, 2018 [https://tinyurl.com/y8hu82lt].

The mechanism by which rising oil prices caused by the January 2020 implementation of the IMO sulfur rule will affect the global economy is well understood. Petroleum product prices rise. Consumers in all countries, dependent on their vehicles for their livelihood, will have to allocate a larger share of their disposable income to fuels and cut expenditures on other items such as entertainment, vehicle purchases, or housing. As Hamilton noted, "A consumer who fails to reduce the quantity purchased of an item by as much in percentage terms as its price goes up will find that the item comes to consume an ever-larger fraction of her budget."[9]

Here I explain in detail the problems in the petroleum industry that threaten such serious damage to the global economy. I also offer suggestions for strategies policymakers could adopt today to prevent this Armageddon. Very high diesel prices and global recession or depression are not inevitable. Action, though, is required.

Background: The IMO 2020 Rule and Maritime Compliance Options

The IMO adopted a rule in 2008 that contemplated removing most sulfur from fuels used in the world's oceangoing vessels, which number more than sixty thousand. The IMO then adopted the sulfur-reduction proposal because sulfur is one of the most significant contributors to ill health in the world. Environmentalists had also called on the world's shipping industry to reduce its contribution to global warming, especially carbon dioxide emissions. If it were a country, the global shipping industry would rank as the sixth largest emitter of greenhouse gasses worldwide.[10]

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[9] Hamilton, p. 219.
[10] Nancy Vandycke and Dominik Englert, "Three reasons why maritime transport must act on climate change," The World Bank Transport for Development Blog, December 14, 2017 [https://tinyurl.com/ybsxmlzv].

The IMO's action followed steps taken in all industrialized nations and most emerging countries to remove sulfur from petroleum products. The US EPA, for example, had begun such a regulatory program for diesel in 1993.

The IMO members agreed that the industry would act to reduce emissions. In 2008, the organization announced that action would be taken between 2020 and 2025. In 2016, the IMO agreed that the final rules would go into effect in 2020. Environmental groups welcomed this decision. Shipping has long been viewed as an outlier—or even an outlaw—by those seeking a global reduction of harmful gasses.

The world shipping industry could comply with the IMO 2020 regulation in three very different ways. First, shipowners could convert existing vessels to burn liquified natural gas. LNG contains almost no sulfur, and thus a move to burn it is an obvious, perhaps even optimal, means of compliance. Using LNG as marine fuel faces two obstacles, however. On the one hand, it is very expensive and so beyond the means of an industry that has earned minimal profits for years. On the other, the LNG distribution system in 2016 was not fully developed, and it was not clear that the fuel would be widely available in 2020.

Second, shipowners could install scrubbers to remove sulfur from engine exhaust. These devices are used widely on land at coal-fired electric power stations.

Third, shipowners could do nothing, putting the onus on the oil industry to provide the needed 0.5-percent-sulfur fuel by 2020. In 2016, the capital-constrained owners viewed this as their best option.

The problem, though, is that the oil industry may not have the capacity to supply the fuel. In 2016, many of those focused on the IMO decision-making progress had this concern. One refining expert told

Reuters after the agency's 2016 meeting that refiners unable to convert residual fuel oil would struggle to remain profitable as their markets for high-sulfur fuel oil shrank to almost nothing. He added that "refiners will not invest to de-sulfurize fuel oil and [thus] there is not enough low-sulfur fuel oil to meet demand from the shipping sector."[11]

Some also doubt that shipowners would comply fully with the IMO regulation. Observers in 2016 and 2018 have suggested that ten to twenty percent of owners would find ways to evade the rule. In recent months, though, the IMO has proposed strong regulations that make noncompliance a risky option. Another possible deterrent would be to deem a ship using noncompliant fuel unseaworthy, which would nullify its insurance coverage. Thus, as 2020 approaches, it appears most shipping firms intend to come into compliance by using low-sulfur fuel. They seem to be ignoring the fact that this fuel may not be available or, if available, exorbitantly costly.

The Low-Sulfur Diesel/Gasoil Supply Squeeze

Between 2016 and 2018, many of the circumstances that convinced most IMO members of the feasibility of the world shifting to low-sulfur marine fuel by 2020 changed. Oil production in Venezuela, a major player in the global oil market, collapsed. OPEC, Russia, and several other producing countries reduced output to force inventory liquidations and raise prices. To top it off, in 2018 the United States seems intent on reinstating sanctions on Iran, possibly removing a crude supply source that might be essential in cushioning price increases. These events and actions will all influence market developments in 2020 when the IMO rule becomes effective.

[11] Jonathan Saul, "U.N. sets rules to cut sulfur emissions by ships from 2020," Reuters, October 27, 2016 [https://tinyurl.com/y88wfsuq].

These changes matter because the amount of crude available for refining has a direct impact on the availability of diesel fuel. At the most basic level, world refiners can produce roughly five hundred sixty thousand barrels of diesel from every million barrels of crude refined, according to Morgan Stanley analysts. This “rule of thumb” dictates that 1.8 million barrels per day of crude must be refined to produce one million barrels per day of diesel.

This conversion rule of thumb can be further refined. Data published in the authoritative *BP Statistical Yearbook of World Energy* shows that twenty-eight percent of the global fuel supply is diesel or gasoil. Most of this product produced in 2017 contained less than 0.5-percent sulfur and would qualify for use as marine fuel.[12] Future production will be the same.

This calculation is critical because it allows us to estimate the crude volume that must be produced in 2018 to meet current consumer demand and the coming demand from the maritime industry. BP’s statisticians estimate that global diesel consumption in 2017 totaled 27.8 million barrels per day. Almost none of this fuel was consumed by the maritime industry, which means consumption will total around 28.5 million barrels per day in 2020 before the incremental demand from ocean-borne shipping is added. An additional one to two million barrels per day will be required to provide marine fuel that meets the IMO 2020 standard. In round numbers, global gasoil/distillate supply will need to increase to thirty million barrels per day.

[12] Credit for this simple calculation goes to analysts at Morgan Stanley. See Martijn Rats et al., “Countdown to IMO 2020; Not Plain Sailing,” Morgan Stanley Research, May 15, 2018, p. 56.

Total crude supply will need to rise to one hundred million barrels per day in 2020 to meet this demand.[13] This assumes that global distillate production from crude remains at twenty-eight percent.[14]

Global crude production of one hundred million barrels per day in 2020 would require an eight-percent increase in output from 2017. The annual rate of increase would need to be three percent per year, three times the rate of increase for the last decade. Achieving this boost will be difficult, if not impossible, should the changes in the global supply situation noted at the start of the section—Venezuela's production decline, OPEC's output restraint, and the reinstatement of US sanctions on Iran—remain unchanged.

The collapse of Venezuela's oil production was not anticipated in 2016. Oil output from the country totaled around two million barrels per day when the IMO program was ratified. Two years later, output has declined to 1.5 million barrels per day. By 2020, Venezuela may be producing no crude, which would remove 1.5 million barrels per day from the global market.

OPEC's effort to raise crude oil prices by reducing production has had a side impact. The world's inventory cushion, which might have been used to meet the increased demand for low-sulfur distillate stemming from the IMO 2020 rule, has shrunk.

To reiterate, since the crude oil price collapse that began in 2015, ministers from oil-exporting countries have focused on global inventories. Saudi oil minister Khalid al-Falih and his Russian counterpart Alexander Novak have worked closely to lower global oil stocks. Their actions were taken to raise prices,

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[13] Total requirement for crude and natural gas liquids, as well as refinery gains, will be roughly one hundred seven to one hundred eight million barrels per day. Refinery gains and NGLs total around seven million barrels per day today. Thus, actual crude requirements will total one hundred million barrels per day.

[14] As noted below, there is concern that this percentage will fall, meaning even more crude will be required.

and they succeeded. Global commercial crude stocks have decreased around one hundred fifty million barrels over the past year, while commercial middle distillate stocks (diesel fuel) have dropped one hundred million barrels. Applying the Morgan Stanley "rule of thumb," the potential loss in distillate supply associated with OPEC's 2017 effort to raise prices will cut the amount of oil available from inventories in 2020 by almost two hundred million barrels, or around five hundred thousand barrels per day.

The Trump administration's decision to renew US sanctions on Iran will remove a crude supply source that might be essential in moderating price increases. The sanctions will probably take around eight hundred thousand barrels per day from global supply. This estimate is based on the impact the previous sanctions had on Iran. Data published by *The Wall Street Journal* highlight that loss.[15] The *WSJ* authors graph Iran's domestic consumption and exports by month from January 2010 to March of this year. Their combined decline reached a maximum of eight hundred thousand barrels per day while the sanctions were in force.

Taken together, the loss of Venezuelan output, the inventory reduction engineered by OPEC, Russia, and a few other producers, and the renewed sanctions on Iran will subtract 2.5 to three million barrels per day from the market. The supply squeeze is illustrated in Table 2 (page 20). The first column in this table shows the oil volumes produced in 2017. The second column shows the volumes **that would have been produced in 2017 had sanctions on Iran been in effect that year and had Venezuela's output collapsed.**

[15] Bill Spindle and Anant Vijay Kala, "Buyers of Iran's Oil Balk at U.S. Push to Isolate Country," *The Wall Street Journal*, June 10, 2018 [https://tinyurl.com/y92uh5tn].

Table 2. World Crude Oil Production in 2017 As Reported, As Would Have Occurred with the Loss of Venezuelan and Iranian Crude, and As Might Occur in 2020 (Thousand Barrels per Day)

	2017 as Reported	2017 with Iranian and Venezuelan Outages	Potential 2020
Non-OPEC			
Americas			
US	13,057	13,057	16,657
Canada	4,831	4,831	5,431
Mexico	2,224	2,224	1,924
Brazil	2,734	2,734	3,534
Colombia	851	851	851
Total South/Central America except Venezuela, Ecuador, Brazil, and Colombia	956	956	1,156
Europe			
Norway	1,969	1,969	2,069
United Kingdom	999	999	999
Other Europe	551	551	551
Russian Federation	11,257	11,257	11,557
Azerbaijan	795	795	795
Kazakhstan	1,835	1,835	1,935
Other CIS	401	401	401
Africa			
Egypt	660	660	760
Other Africa except OPEC Nations			
Middle East	946	946	996
Oman	971	971	971
Other Middle East except OPEC nations	297	297	297
Asia			
China	3,846	3,846	3,646
India	865	865	865
Indonesia	949	949	929
Malaysia	697	697	647
Thailand	465	465	445
Vietnam	335	335	285
Other Asia-Pacific	722	722	672
OPEC			
Algeria	1,540	1,540	1,490
Angola	1,674	1,674	1,654
Ecuador	531	531	531
Equatorial Guinea	199	199	199
Gabon	200	200	200
Iran	4,982	3,700	2,700
Iraq	4,520	4,520	4,920
Kuwait	3,025	3,025	3,525
Libya	865	865	865
Nigeria	1,988	1,988	1,988
Qatar	1,916	1,916	1,916
Republic of Congo	291	291	361
Saudi Arabia	11,951	11,951	12,000
United Arab Emirates	3,935	3,935	4,000
Venezuela	2,110	500	500
Total	92,940	90,048	95,222

Source: *BP Statistical Review of World Energy*; PKVerleger LLC.

Simple arithmetic shows that the 2017 global production reported by BP would be ninety million barrels per day, not the published figure of 92.6 million barrels per day.

The adjustment to 2017 data lays a foundation for comparing projected 2020 global output with the likely availability.

Column 3 of Table 2 shows the likely volume of crude production in 2020, assuming the sanctions on Iran are in effect and Venezuelan output continues to decline. These decreases are offset by greater output from the US and other countries, particularly Saudi Arabia.

The fourth column of Table 2 shows the likely level of output in 2020 with the increases in US and Canadian production and other parts of the world, excluding any increase by Saudi Arabia or the UAE. These countries are viewed as "swing producers." The incremental need for their output is discussed below.

Table 3. Comparison of Projected Crude Oil Supply with Indicated Requirements for 2020 (Thousand Barrels per Day)

Indicated Supply (from Table 1)	95,222
Likely Requirement to Meet Global Demand, Assuming No Recession	97,640
Additional Requirement before Adjusting for IMO 2020	2,418
Additional Requirement based on a 28% Distillate Yield	3,571
Total Additional Requirements	5,989

Source: PKVerleger LLC.

Table 3 summarizes the situation. It reveals the production increase shown in Column 3 of Table 2 would leave a yawning supply gap absent a recession even if the IMO regulatory threat did not overhang the market. The first row of the table shows the indicated supply for 2020 taken from Table 2. The second shows the amount required if the projections by the IEA materialize. The difference is 2.4 million barrels per day. This gap can be replaced by more production from Saudi Arabia and the UAE. That increase, however, would likely eliminate most or all the surplus global production capacity, which the IEA estimated to be three million barrels per day in *Oil 2018*.

Sanctions on Iran combined with the Venezuelan oil industry's collapse, in short, will exhaust global surplus production capacity by 2020, assuming the economic expansion continues at the present rate. This implies no incremental crude oil productive capacity will be available should more be required to meet the IMO 2020 regulation. Indeed, as can be seen from Table 3, a further 3.5 million barrels per day will be needed to produce the one million barrels per day of incremental low-sulfur diesel the IEA predicts will be required (see the first row of Table 1 above).

An increase in production of 3.5 million barrels per day is unlikely. Instead, distillate prices will almost certainly increase. A review of retail distillate prices in the fifteen countries accounting for approximately sixty percent of global distillate consumption shows that the average price in 2018 is $1.10 per liter or $4.15 per gallon. The US price is lower at $0.85 per liter ($3.24 per gallon), while prices are highest in France, Italy, and the United Kingdom at $1.7 per liter or almost $7 per gallon.

Consumption in the fifteen countries totals seventeen million barrels per day. BP reports that global distillate consumption totaled 27.7 million barrels per day. A nine-hundred-thousand-barrel-per-day reduction in consumption in nonmaritime use can be achieved, assuming the price elasticity of demand is -0.1, with a $60-per-barrel distillate price increase. This decrease would free one million barrels per day of ULSD for sale as marine fuel.

The $60-per-barrel distillate price increase would translate to $1.40 per gallon at retail in the US or €0.5 per liter in Italy. Spot distillate prices would rise between $450 and $500 per tonne in Rotterdam, taking prices will over $1,000 per tonne. The increase in distillate prices would likely take light sweet crude prices from current levels of $70 per barrel to perhaps $130, again assuming the global economy continues to expand at its current rate. Appendix I provides a full explanation of the calculation procedure.

These estimates assume consumers in every country accept the higher prices. This assumption is questionable, however. Recently, truck drivers in Brazil brought the nation to a standstill while demanding lower diesel prices. Eventually, the Brazilian government gave in to the drivers' demands when gasoline stations ran dry and grocery store shelves emptied. The president cut the diesel price twelve percent, reduced the road tolls paid by trucks, and offered other benefits to end the strike.[16]

Truck drivers in other countries could respond in the same way to high prices. The price increase required to balance the world market would go up if they did so and governments placated them by raising subsidies. Globally, diesel prices might have to rise by $70 per barrel to achieve the same reduction in use if some nations acted to protect their trucking industry from greater fuel costs.

The higher diesel prices will lead to higher crude prices. Statistical tests comparing the change in the Dated Brent prices to the change in spot prices of New York Harbor low-sulfur distillate reveal a dollar-for-dollar passthrough. (Appendix II documents this relationship.) A similar relationship exists between the Dated Brent price and the spot price of low-sulfur gasoil in Rotterdam.

The clear conclusion from this analysis is that the price of Dated Brent and other light sweet crudes will follow the price of low-sulfur diesel/gasoil upward. Should the latter's prices rise $60 per barrel, as I suggest they might, the prices for light sweet crude oil will rise by the same amount. An increase of this

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[16] See Shasta Darlington and Manuela Andreoni, "Truckers' Strike Paralyzes Brazil as President Courts Investors," *The New York Times*, May 28, 2018 [https://tinyurl.com/yccwx3j5].

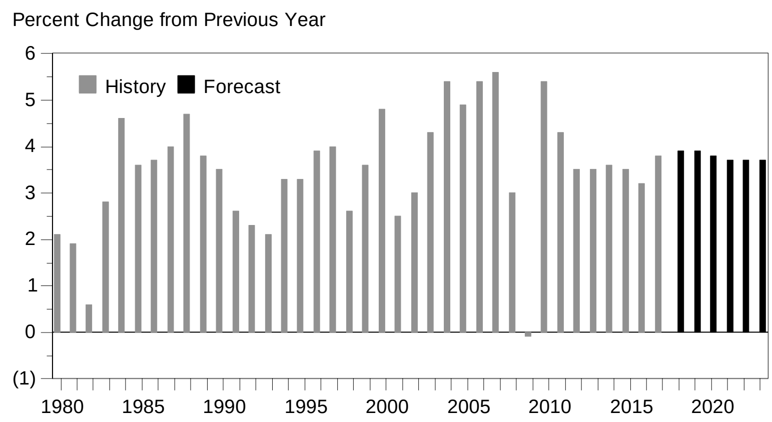
amount implies a Dated Brent price between $130 and $140 per barrel, a level very close to the prices seen in 2008.

Believe it or not, this prediction must be viewed as optimistic even though the economic consequences of oil selling for $130 per barrel would be terrible. It is optimistic because it assumes market disruptions will be limited to a loss of Iranian crude and the collapse of Venezuelan output. It also assumes the pipeline constraints that keep US “light tight” crude oil (LTO) away from the market today will be resolved and that world refiners will be able to process the LTOs. Finally, it assumes that production in Canada, Libya, and Nigeria continues uninterrupted and that no other disruptive events occur. These assumptions rely on the following developments, none of which are assured.

> US LTO production is limited today by a lack of pipeline capacity to take it to refineries in Texas and Gulf Coast ports for export. Exploration efforts are being slowed by this deficiency. New pipelines have been planned to eliminate these bottlenecks by 2020. My forecast assumes these will be completed and LTO production will increase.
>
> US LTOs may create problems for refineries even if they get to market. These crudes are very light. Many refiners must blend other crudes with them before processing. The analysis here assumes this obstacle will be overcome.
>
> The simulations also assume that no other disruptions happen in the international crude market. Within the last decade, Nigeria and Libya have often seen their output affected by political events, while Canadian producers have been plagued by forest fires and problems at key upgrading facilities. Even a moderate disruption could boost crude prices $10 to $20 per barrel.

The upward progression of crude oil prices could be slowed if growth in the global economy decelerates. The projections in *Oil 2018* are based on the International Monetary Fund's 2017 *World Economic Outlook*, which predicts world growth of 3.9 percent in 2018 and 2019 and 3.7 percent in 2020. Oil consumption would be lower during an economic slowdown, as might occur with a global trade war and/or the spread of populism and uncertainty in key regions such as Europe.

Figure 5
Year-to-Year Change in World Real GDP, History and Forecast



Source: IMF.

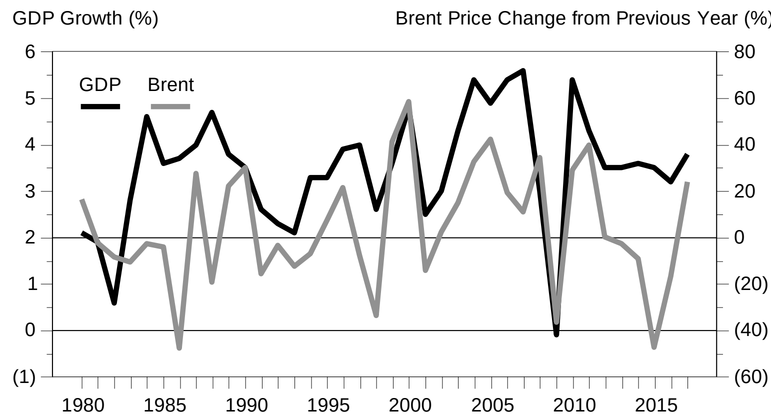
However, the statistics on global growth suggest a slowdown is unlikely. As can be seen from Figure 5, global growth rates have been remarkably constant at three to four percent from 1980 to 2017, averaging 3.5 percent per year. The standard error is 1.2 percentage points. The most recent IMF forecast sees growth continuing at a rate of 3.7 percent per year through 2023.

Absent an economic disruption such as what might be caused by the IMO sulfur rule, this level of growth looks to continue.

Economic Impacts of High Oil Prices in 2020

The rise in world crude prices could have serious impacts on world economic growth unless the IMO revises its 2020 marine fuel regulation. The effect of IMO inaction on the world economy, and that of the United States especially, could be severe.

Figure 6
Global GDP Growth vs. Year-over-Year Change in Brent Spot Prices, 1980 to 2018



Source: IMF; BP.

Figure 6 illustrates the imperfect relationship between crude prices and global growth. This graph shows the growth rate of global GDP as published by the IMF and the year-over-year change in the Dated Brent price. If the two major monetary or financial disruptions that took place over the last forty years are excluded, lower oil prices are associated with higher growth and vice versa.[17]

The US economy is one of the most vulnerable to oil price fluctuations because fuel prices are lower here and per-capita consumption higher than in most European countries, Japan, or China. This vulnerability occurs because the taxation on petroleum products is much lower in the United States. Thus, a $60-per-barrel price increase for diesel and crude oil would have a much larger impact on the US

[17] The two major disruptions were the period of very high interest rates associated with the Volcker Federal Reserve in the early 1980s and the 2008/2009 global financial collapse.

economy than the economies of many other industrialized nations. This impact would remain large despite the presence of a robust energy industry in North Dakota, New Mexico, Oklahoma, and Texas.

Table 4 shows the impact on the United States, Germany, Italy, and France of a $60-per-barrel increase in crude oil prices. The calculation is based on the amount of petroleum consumed in these countries annually (shown in the table's first column). The estimated average product prices for each nation, including tax, per liter and barrel appear in the second and third columns. The calculated total expenditures at these prices are shown in the fourth column and the country's GDP in the fifth column.

Table 4. Share of GDP Allocated to Petroleum Purchases in Four Countries Following a $60-per-Barrel Price Increase

	Consumption (mbd)	Price including Taxes ($/liter)	Price Including Taxes ($/barrel)	Fuel Expenditures ($ trillion)	GDP (US$)	Expenditures as % of GDP	Expenditures with $60/Barrel Price Increase as % of GDP	Change in Share of GDP (%)
US	19,880	0.8	127.18	0.92	18.624	4.95	7.29	2.34
Germany	2,470	1.6	254.35	0.23	3.777	6.07	7.50	1.43
Italy	1,280	1.8	286.15	0.13	1.850	7.23	8.74	1.52
France	1,710	1.7	270.15	0.17	2.465	6.84	8.36	1.52

Source: IEA; *BP Statistical Review of World Energy*; IMF; PKVerleger LLC.

The sixth and seven columns of the table show the fuel expenditures as a percentage of GDP at current prices and with the $60-per-barrel increase noted above. Note that the share of GDP (assuming a recession does not occur) rises in the US by 2.34 percentage points but only around 1.4 percentage points in the three European countries. The impacts on consumers in Japan would be greater than in European countries because taxes there are lower. China and India would also experience a larger burden.

In the United States, the higher prices would initially impact individual consumers, forcing them to cut consumption of other goods. Hamilton has documented this impact in several studies.[18] He shows that consumers reduce spending on other items when fuel prices rise. Those cuts have multiplier effects that lead to reduced activity across the economy. The US auto industry, for example, confronted serious financial difficulty in late 2007 and 2008, before Lehman Brothers failed, due to rising gasoline prices. New car sales fell five million units, dropping from sixteen million units in December 2007 to thirteen million units in September 2008

The impacts of several economic disruptions are captured in Table 5. This table shows four disruption episodes, the episode date, the drop in total consumption as a percentage of GDP, the oil price increase, and the drop in GDP associated with the oil-price increase.

Table 5. Total US Consumption Loss as a % of GDP During Four Crude Oil Spike Episodes

Episode	Episode Year	Consumption Loss on All Items except Energy as a % of GDP	Oil Price Increase (%)	GDP Decline (%)
Arab Embargo	1973	0.48	61.9	1.6
Fall of Shah of Iran	1979	0.77	102.4	0.8
Invasion of Iraq	1990	0.38	32.2	0.0
2007/08 Price Increase	2007	0.77	79.9	2.5

Source: PKVerleger LLC.

Table 5 provides a means of calibrating the impact of the $60-per-barrel crude oil price increase discussed above. For my purposes here, I estimate the increase to be eighty percent. This raise would require consumers to reduce expenditures on everything but energy between 0.6 and 0.8 percent. The

[18] See Hamilton, Footnote 7.

dollar reduction would amount to $100 billion. After an adjustment for multiplier effects, nominal GDP would be reduced by one percent.

The impact could be far larger if other events conspire to drive prices higher. An increase of $100 per barrel in crude prices could cut almost two percentage points from GDP.

The impacts on emerging nations could be larger. Countries that have issued large amounts of dollar-denominated debt could be in serious difficulty. Their situation today is already precarious. US tax reform, which encouraged companies to repatriate dollars, has reduced the availability of funding for them. Meanwhile, the slowdown in Europe has cut their markets, and the strengthening dollar has worsened their situation. A large oil price increase could create a catastrophe where debt cannot be serviced, and a situation such as the Asian debt crisis of 1997 could result. In short, the macroeconomic effects resulting from the oil-price increase caused by the implementation of the IMO 2020 sulfur regulation are not trivial.

Policies or Developments that Might Moderate the IMO 2020 Impact

Eighteen months remain before the IMO 2020 rule takes effect. There is, in theory, still time to modify the regulation. However, IMO officials have made it clear that little room for maneuver exists. In mid-May, S&P Global Platts interviewed Kitack Lim, the IMO's secretary-general, about the possibility of revision, asking him this question: "If serious problems with implementing the sulfur limit rule become apparent in early 2019, would you advocate putting it on hold temporarily?"

Lim's answer was blunt:

> "At this point, the regulation which brings into force the 0.5% limit in sulfur in fuel oil from January 1, 2020 (outside designated emission control areas where the limit is already 0.1%) cannot be changed from a legal perspective, so there is no possibility of delay."[19]

This would seem to be the final word. However, **one expects that emergency modifications to the rule could be made if it were causing serious economic dislocations**. The European Union, the IMF, and leading Asian countries could likely force a change under dire circumstances.

However, the crisis would need to be extreme. The market impact would have already been felt, particularly in the United States. Any action taken would probably occur after the economic collapse was well under way, just as the financial problems that caused the 2008 meltdown were only addressed after 2008.

In this debate, the United States has no leverage. Many IMO members, particularly those in Europe, strongly favor moving ahead with the implementation on January 1, 2020. These members see global warming as a serious issue and strongly favor the Paris Accords adopted in 2016. The United States withdrew from that agreement in 2017. Thus, one can envision the IMO members refusing to moderate the 2020 rule unless the United States reverses course and ratifies the Paris climate agreement.

The United States has no control over the IMO and so can do nothing on its own. It is part of a very small minority there. At a recent meeting, the agency's environmental committee announced a program to

[19] Surabhi Sahu and Jack Jordan, "Interview: IMO head says 'no possibility of delay' to sulfur limit rule for marine fuels," S&P Global Platts, May 18, 2018.

reduce the shipping industry's greenhouse gas emissions.[20] This move was opposed by three countries: the United States, Brazil, and Saudi Arabia.[21] The other one hundred seventy-one members voted in favor of the action.

The Trump administration's trade policy will further weaken the willingness of other nations to ease restrictions to help the US. The United States has followed an aggressive unilateral trade strategy since Donald Trump became president. His administration's policies have left many frustrated and angry. The upcoming economic squeeze tied to the IMO rule provides them a way to even the score.

One option available to the United States to ease the IMO 2020 transition unilaterally would be releasing oil from its Strategic Petroleum Reserve. The SPR holds six hundred sixty million barrels. Sweet crude oils, which may have high distillate yields, account for two hundred fifty-four million barrels, while sour barrels total four hundred five million barrels. Processing the sweet barrels held in the reserve may provide the additional low-sulfur fuel needed to smooth the changeover, assuming this oil has a high distillate yield.

Specifically, the United States may be able to increase the supply of low-sulfur bunker fuels exchanging the desirable high-distillate-yield crudes with buyers from the US or other countries for less desirable crudes. This approach depends on at least some of the light oil held in the US reserve having a high yield of low-sulfur diesel. In return for this crude, the recipients could be required to replace it with other types of oil. For example, a Chinese buyer could boost its supply of low-sulfur diesel by refining oil from

[20] "IMO gives strong signal to the shipping industry to start decarbonizing," *Hellenic Shipping News*, April 14, 2018 [https://tinyurl.com/yanbmk5o].
[21] Jean Chemnick, "U.N Agency Agrees to Path for Shipping Emissions Cuts," *Scientific American*, April 16, 2018 [https://tinyurl.com/ybo925t3].

the SPR and in return buy oil from the US Permian Basin for an offsetting transfer to the reserve. Such transactions might moderate the economic impacts from the IMO 2020 implementation.

Failure to comply with the IMO 2020 rule could also ease the transition. The increase in the price of low-sulfur marine fuels might encourage noncompliance or less than full compliance with the regulation. Following the 2016 IMO decision, many observers predicted that compliance would not be universal. Some shippers may try to evade the regulation if prices rise to the extreme levels feared here.

Noncompliance, though, would be risky. As I noted, the IMO has taken steps to discourage it, including passing measures that would invalidate the insurance of any vessels or cargos found to be in violation of the rule. Furthermore, most bunker fuel is consumed by very large shipping companies that dare not risk such violations. Thus, widespread evasion is unlikely.

A serious trade war would also lessen the impact of the IMO rule. Economic policies being followed by the Trump administration threaten to reduce the amount of goods moving in international trade. Ironically, a trade war could decrease the amount of fuel used in international commerce, which would lessen the sulfur rule's impact.

Conclusion

The IMO regulation on marine-fuel sulfur content, if left unchanged, will likely have widespread impacts on the petroleum sector. Crude oil prices could rise to $160 per barrel or higher as the rule takes effect, assuming no market disruptions. Prices could rise much higher with any disruption, even a moderate one. The higher prices will slow economic growth. If they breach $200 per barrel, they would likely lead to a recession or worse.

The risk of high prices and an attendant economic downturn should force government policymakers across the globe to review the IMO 2020 issue. As of this writing, though, on July 1, 2018, no such reviews are being conducted. Instead, the global economy is moving steadily toward a crisis yet unseen by most, if not all, key individuals in policy positions. Soon it will be too late to act. Very high prices and recession await.

Appendix I

Calculating the Impact of Higher Diesel Prices on Retail Diesel Fuel Consumption

The table on the following page presents the data and the approach used here to calculate the impact of higher diesel retail prices on diesel fuel consumption in fifteen countries. I started with a very simple price elasticity approach that assumes that the percentage decline in consumption in a country depends on the percentage increase in retail price. The model was created in a way that allowed the use of alternative price elasticities. For this test, the same price elasticity, -0.1, was used for each country.

The calculation relies on retail diesel consumption data published by the Energy Intelligence Group (EIG) for the fifteen countries shown in the table. The consumption by country is listed in Column 1. Column 2 shows the totals for regions. The countries covered by EIG consumed seventeen million barrels per day of diesel/gasoil in 2017.

The BP statistical yearbook reports consumption for all countries in the world. Global consumption of diesel/gasoil in 2017 as published by BP was 27.7 million barrels per day. Thus, the table's sample covers sixty-two percent of total consumption.

I obtained retail prices from the IEA and local sources and converted prices to US dollars using current exchange rates. These are shown in Column 3 and are generally for the first quarter of 2018. The third column shows the prices per US gallon.

A uniform dollar per gallon (or dollar per liter) increase in price was calculated for each country on the expectation that increases in world crude prices would be passed through by the same dollar per barrel,

Impact of Higher Retail Diesel Prices on Diesel Consumption in Fifteen Countries

	Diesel/Gasoil Use (mbd)		Price/Liter (US$)	Price/Gallon (US$)	% Change in Retail Price	% Change in Use	Adjusted Quantity Consumed (mbd)
North America		4,913					
United States	3,938		0.86	3.24	44.0	-4.4	3,765
Mexico	394		0.95	3.60	39.7	-4.0	378
Canada	582		1.02	3.87	36.9	-3.7	560
South America		944					
Brazil	944		0.90	3.41	41.9	-4.2	904
Europe		4,426					
Germany	1,132		1.50	5.67	25.2	-2.5	1,104
France	976		1.71	6.49	22.0	-2.2	954
Italy	553		1.76	6.67	21.4	-2.1	541
Spain	630		1.44	5.43	26.3	-2.6	613
United Kingdom	655		1.74	6.59	21.7	-2.2	641
Turkey	480		1.24	4.69	30.4	-3.0	466
Asia		6,810					
Japan	771		1.15	4.36	32.8	-3.3	746
China	3,485		0.82	3.10	46.0	-4.6	3,325
South Korea	507		1.26	4.77	30.0	-3.0	492
India	1,633		1.12	4.23	33.8	-3.4	1,578
Thailand	414		0.91	3.44	41.5	-4.1	397
Total		17,094					16,463
% of BP Total		62					
BP Total		27,775					

Source: EIG; PKVerleger LLC.

dollar per gallon, or dollar per liter amount. In some cases, this assumption may be questioned.[22] Calculated price increases would need to be larger if prices in some countries are restricted by controls.

The scenario shown here reflects the price increase needed to reduce global consumption of gasoil/diesel fuel by one million barrels per day. As noted in the text, the increase was determined to be $60 per barrel ($0.38 per liter, $1.43 per gallon, or $464 per metric ton).

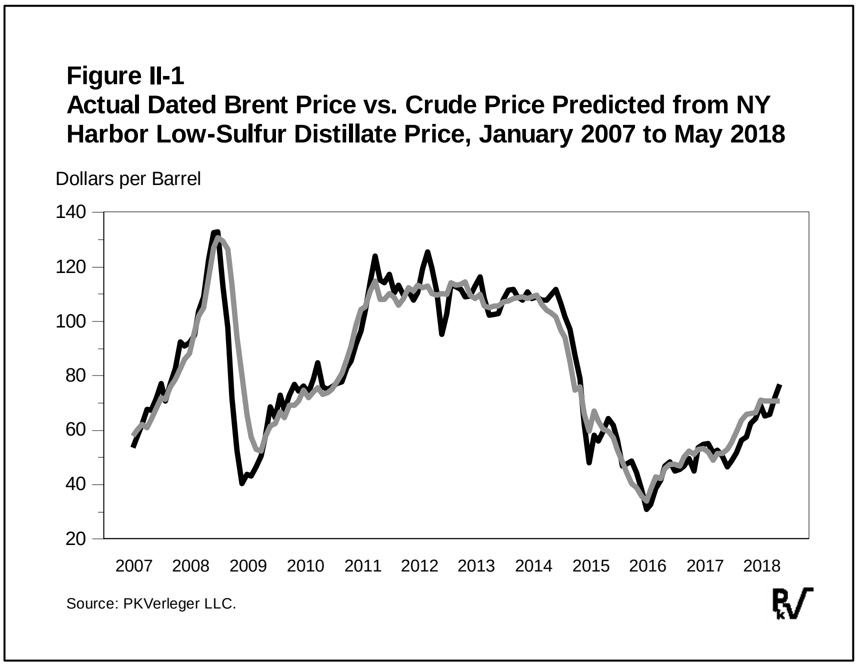
[22] Brazil, for example, was forced to rescind increases in diesel prices in May. See Shasta Darlington and Manuela Andreoni, "Truckers' Strike Paralyzes Brazil as President Courts Investors," *The New York Times*, May 28, 2018 [https://tinyurl.com/yccwx3j5].

Column 4 shows the percentage increase in price per country. The percentage is higher for countries with lower diesel prices and lower for countries with higher diesel prices. For example, diesel prices must rise forty-four percent in the US but only twenty-one percent in Italy because Italians pay almost twice as much per liter (or gallon) as consumers in the US.

The percentage change in consumption for each country is shown in Column 6. The final lower amount of consumption is shown in Column 7.

Appendix II
Link between Crude Prices and Low-Sulfur Distillate Fuel Oil Prices

Figure II-1 below compares actual Dated Brent prices with the price predicted from low-sulfur distillate prices. The simulated value is based entirely on changes in distillate prices without error correction. The simulation starts using the actual average Dated Brent value for December 2006.



The statistical equation used in the calculation regresses the change in Dated Brent price on the change in the low-sulfur distillate price in New York Harbor. Four change variables are used: the change from the first to second month, from the second to the third month, from the third to the fourth month, and from the fourth to the fifth month. The four variables are needed because the data reveal that crude prices move slowly after a change in distillate price.

The regression was estimated in first difference form as follows:

$$\Delta Brent_t = \alpha\Delta Ho_t + \beta\Delta Ho_{t-1} + \gamma\Delta Ho_{t-2} + \mu\Delta Ho_{t-3} + \varepsilon_t$$

where $\Delta Brent_t$ measures the change in Brent from month t-s to month t, and Ho_t measures the change in heating oil prices from month t-1 to 1. Three lagged values of this value are used.

I estimated the equation from January 2007 to March 2018 using monthly data. The fitted values used in the equation, shown in the table below, were calculated using the December 2006 price of Dated Brent and the values of changes in heating oil going forward with no error correction. Thus, the May 2018 estimated value is based on the December 2006 Brent price and the subsequent changes in heating oil. The equation results convince me that the change in heating oil prices is fully passed on to the Brent price.

Fitted Values for Crude Oil/Distillate Fuel Oil Price Regression Equation

Parameter	Estimate	Standard Error	t-statistic
α	0.37	0.07	5.64
β	0.04	0.07	0.58
μ	0.05	0.07	0.78
γ	0.45	0.07	6.89

Source: PKVerleger LLC.

The equation explains forty-six percent of the variance in Dated Brent prices. The standard error was $5 per barrel.