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The likely implications of the new IMO standards on the shipping industry

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ABSTRACT

Discussions about "peak oil demand" tend to focus on passenger vehicles, often from a US and European perspective. These discussions often ignore other markets, such as marine transport, which collectively would also need to show a reduction in demand if oil consumption were to reach an inflection point. We explore the outlook for marine bunkers, a niche market that accounts, depending on estimates, for up to 7% of the demand barrel. We focus on the possible impact of new environmental restrictions that aim to drastically reduce sulfur oxide (SOx) emissions from ships as of January 2020, placing them against the background of past innovations that have been reshaping ships' fuel consumption patterns and assessing their likely impact on future innovation in the sector. We conclude that the rules might paradoxically end up slowing down what might have otherwise been a more rapid transition of the shipping market away from traditional bunker fuels. The rules will, however, adversely affect simple refineries and producers of heavy, sour crude oil grades, whose prices are sometimes indexed to that of high sulfur fuel oil (HSFO).

1. Introduction

New International Maritime Organization (IMO) regulations, due to take effect in January 2020, aim to drastically lower the sulfur cap for air emissions from ships. Lindstad et al. (2015) have argued that IMO's approach of a global sulfur cap is fundamentally flawed, though we posit that changes to IMO's standards are at this point highly unlikely and therefore assume that the rules will be implemented as planned. On current technology, shippers have three main options to meet the new low-sulfur requirements. They can run on liquefied natural gas (LNG); they can continue to use HSFO and process air emissions through an exhaust gas cleaning system (EGCS), more commonly called "scrubber," which must be fitted on board the ship, along with dedicated tanks to hold and treat resulting wastewater from the process; or they can switch from HSFO to a lower-sulfur fuel, such as marine gasoil (MGO) or a new type of residual fuel known as low-sulfur fuel oil (LSFO).[1] Each option has its costs and benefits. Those, however, depend on market conditions that are inherently difficult to foretell. Market unpredictability is further exacerbated by regulatory uncertainty and potential feedback effects from the new standards themselves.

Although the IMO first announced the cleaner-burning bunker rules as far back as 2008, many industry participants, less than two years before the rules' effective date, had yet to decide which of the three paths to compliance to adopt. This has led some industry stakeholders

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[1] LSFO is most often understood to have a sulfur content of 1% and, therefore, does not meet the coming 0.5% S IMO limit, let alone the current and more stringent 0.1% S ECA limit. In response to changing bunker specs, however, several refiners have been offering or developing fuel oil products with a lower sulfur content, and shipping companies have started adopting them. For example, Shell offers a 0.1% S ECA-compliant, ultralow-sulfur oil grade (ULSFO). In this article, LSFO is generally assumed to meet the 0.5% S cap and includes the narrower ULSFO subcategory. See M. Desmarescaux and I. Grigorjeva, "NWE LSFO Premium to HSFO Widens on Weak HSFO Barges, Despite Low LSFO Demand," *Platts*, January 7, 2015, https://www.platts.com/latest-news/oil/london/nwe-lsfo-premium-to-hsfo-widens-on-weak-hsfo-26976395; "Low Sulfur Fuel Oil," *Shell.com*, accessed July 3, 2017, http://www.shell.com/business-customers/marine/fuel/ulsfo.html; and "Shell Trading & Supply: Marine Fuels," *Shell.com*, accessed July 3, 2017, http://www.shell.com/business-customers/marine/fuel/ulsfo/_jcr_content/par/textimage.stream/1473174550832/3b2ee2813d9f9ceb756bd7b5ade60c1ea828f0abe6b8d3f7c1e0364fa6c2aea9/typical-properties-shell-ulsfo.PDF . For an example of a company that has adopted LSFO, see *Q1 2017 Investor Report (*Hapag-Lloyd AG, May 12, 2017) and *Q4 – FY 2016 Investor Report,* (Hapag-Lloyd AG, March 24, 2017*)*, downloaded July 3, 2017 from https://www.hapag-lloyd.com/en/ir/publications/investor-reports.html#tabnav.

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to recommend postponing the rules [2] – a call that may have been encouraged by the fact that the IMO had initially kept open the option of delaying implementation by up to five years, pending the results of a fuel-availability study commissioned from a consortium of third-party consultancies. A final decision on timing was initially planned by end-2018. As such a late decision would not have left much room for unprepared shipowners to comply by 2020, many shippers and market analysts wrongly expected a delay. They were surprised when the IMO, in a bid to give clarity to the market, moved up its final decision and, in October 2016, confirmed January 1, 2020, as the date when the rules would take effect.

Three sets of factors can be identified that discourage a prompt response to the new policies: the financial burden of premature compliance; financial risks stemming from market uncertainty, which is exacerbated by the IMO policy itself; and regulatory uncertainty. Premature compliance can be punishing. MGO and LSFO both trade at a significant premium to HSFO. Shippers have no incentive to use these higher-cost fuels until required. Meanwhile, the LNG and scrubber options both entail multimillion-dollar up-front capital expenditures, including the capital cost of new processing units and storage tanks (for LNG or wastewater), the one-off loss of revenue from laying up ships in dry dock for weeks to be retrofitted, and the permanent opportunity cost of losing deck space and loading capacity to the new equipment. By rushing to respond to the new standards, shippers run the risk of taking on an unnecessary financial burden, and they put themselves at a disadvantage to more circumspect competitors.

The unpredictability of oil and gas prices, and hence of the relative costs and benefits of the various options, is another reason for market participants to remain sidelined. Roughly speaking, investing in an LNG engine makes sense for shippers as long as natural gas prices stay low enough versus oil to offset the engine's up-front cost over the vessel's remaining life-span.[3] The LNG option could prove a losing proposition, however, in the event of a natural gas rally (see Acciaro, 2014, for an analysis of the uncertainties regarding LNG usage in ECA's). However, Burel et al. (2013) concluded that LNG use in certain parts of the shipping sector, e.g. tanker ships in the range from 10.000 to 60.000 DWT can reduce operational costs by 35%, and carbon emissions by 25%. Likewise, installing a scrubber on a ship requires that the HSFO discount (relative to low-sulfur fuel) be wide enough to offset capital and opportunity costs. Switching to low-sulfur fuel will have the advantage of sparing shippers the up-front cost of a scrubber or LNG engine, but it would be a money loser if the low-sulfur-fuel premium exceeded that cost. Forecasting those interfuel price spreads, however, is inherently risky. Delaying a decision, in the hope of gaining more visibility on market direction, thus seems sensible.

Potential feedback effects from the global SOx cap add to this uncertainty. The industry's rate of adoption of the various compliance options will likely affect their competitiveness. Widespread adoption of LNG as bunker fuel would thus boost LNG demand at the margin and support its prices, undermining the business case for this option. Scrubber costs will likely depend in part on the technology's rate of penetration. HSFO prices would plummet in the case of large-scale fuel switching to LSFO or LNG, but then again, they could prove surprisingly resilient if scrubber sales – and thus HSFO demand – exceeded expectations. The first shippers to commit to any given option will necessarily suffer from a deficit of information, and thus put themselves at a disadvantage—leaving it to late respondents to reap the rewards of their patience. This gives shippers an incentive to take their time before staking positions. Similarly, rising rates of adoption can be expected to lower the capital and operating costs of LNG engines and scrubbers via standardization, economies of scale in manufacturing, efficiency gains, and technology improvements – also benefitting late adopters.

Last, regulatory uncertainty gives shippers further reasons to hold back. The global cap only covers SOx emissions but fails to address NOx or GHG, even though those are also due to come under tighter regulations. In March 2018, the IMO adopted an “initial strategy” to cut GHG emissions from ships, including a “level of ambition” set as a 50% reduction in total annual GHG emissions by 2050 versus 2008.[4] This lack of coordination of the IMO's multiple targets further clouds the relative economics of the various paths to SOx compliance. The business case for scrubbers might not work so well if the global cap is extended to NOx or GHG instead of being limited to SOx because scrubbers do not filter out NOx and are relatively carbon intensive. LNG used as a bunker fuel has the advantage of being low in both SOx and NOx emissions. There are, however, some concerns that methane leakage—if not properly contained—could make it a source of relatively high GHG emissions (see also Thomson et al., 2015). This is leading some companies to promote LNG as a sort of “transition” fuel for shipping, arguing that in the long run it will be based on biomethane rather than methane. Burning LSFO or MGO also comes at a cost in GHG if the full life cycle of the fuels is considered, given the carbon intensity of refinery upgrading and desulfurization. Bunker blending to meet the new targets could also call for increased long-haul shipments of blending material. This, in turn, would raise life-cycle emissions from nominally compliant fuels. Uncertainty as to the scope and timing of future NOx and GHG regulations warrants further caution on the part of shipping operators.

With all these reasons not to rush to a decision, the shipping industry's seeming indecisiveness should not come as a surprise. Less than two years before the new standards are to take effect, scrubber penetration remains marginal. By one count, less than 1% of the world's fleet has been equipped with scrubbers.[5] For a while, according to manufaturers, the number of inquiries dramatically increased but new orders remain few and far between. [6] Orders then suddenly took off, but from an extremely low base, and too late to really move the needle by the January 2020 deadline. Given the capacity limits of manufacturers and the long lead times needed to retrofit a ship, or to order and to take delivery of new scrubber-equipped or LNG-fueled vessels, shippers' cautious approach means that, at the end of the day, most of them will go for low-sulfur fuels.

[2] IEA (*Oil 2017*) issued a thinly veiled call for delays or for a more gradual implementation, noting that in the EU diesel sulfur limits, however disruptive they might have been, were progressively introduced. “In the EU, it took over a decade of gradual changes to lower road sulfur limits…Countries in Southern Europe were allowed to delay the implementation of the directive…Each of the options discussed above has its limitations when it comes to wide-scale use as early as 2020…With our forecast…we do not see availability of low-sulfur bunkers in the required volumes…Given the size of the modern global fleet though, this will be an issue well beyond the medium term.” (109 − 110).

[3] This includes the time out of service for modifications (and lead time for design, supply of tank, and equipment), loss of cargo volume, and deadweight.

[4] IMO, “UN body adopts climate change strategy for shipping,” April 13, 2018, http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx.

[5] According to Argus Media, citing consultancy Ensys, only 346 vessels have invested in scrubbing through 2016. Of those, 70% are in ECAs. The global fleet is estimated at around 45,000 vessels. Argus Media, “Changing Regulations for Fuel Oil Sulfur Caps” (online PowerPoint presentation, January 2017). At the time of writing, several leading shippers, including two of the largest container liners, Maersk and Hapag Lloyd, let it be known they would not adopt scrubbers to comply with the IMO rules. On the other hand, Carnival Corp., a leading cruise ship operator, was reported to have completed scrubber installations on 60 of its vessels. (“This Is Why Maersk Will Not Be Using Scrubbers When the 0.50% Global Sulfur Cap on Bunkers Comes into Force in 2020,” *Ship & Bunker*, May 18, 2017, https://shipandbunker.com/news/world/224210-this-is-why-maersk-will-not-be-using-scrubbers-when-the-050-global-sulfur-cap-on-bunkers-comes-into-force-in-2020).

[6] Halff, “IMO Roundtable,” July 2017, 7–8. Most scrubber orders are for new builds. Demand for retrofits of existing ships is limited by the need to amortize the investment over the remaining life of the ship.

Against all this uncertainty, some analysts have warned that oil prices were bound to undergo dramatic increases in the early 2020s, once delay is no longer an option for shippers and a sudden surge in demand for low-sulfur fuels from the marine sector bumps against global refining capacity to produce those fuels. This paper does not support all too alarmist forecasts for both structural reasons, and anticipated responses from refiners in the run-up to, and even after, 2020. In it, we highlight the role of innovation in shipping and review some of the economic, technological, and policy-driven factors that have been reshaping marine fuel consumption patterns and that will shape the effect of the sulfur cap, including industry restructuring, slow steaming, changes in ship design, digitalization, and fuel switching to LNG and electric batteries. We then proceed to examine how and to what extent the global sulfur cap might further accelerate innovation and transform the sector. Then, we consider the likely impact of the IMO's global sulfur cap on crude oil and refined product markets, and what likely reactions to anticipate from refiners. We end with some brief conclusions and recommendations for future policy.

2. Sea change in shipping markets

The new IMO regulations on sulfur emissions from ships due to take effect in 2020 – "IMO 2020" for short – are not happening in a vacuum. Their effect on fuel markets will depend in large part on the underlying dynamics of the marine sector – a notoriously opaque segment of the oil market. Studies that expect steep oil price gains from IMO 2020 tend to assume strong underlying fuel demand growth from the shipping sector. Yet there is scarce evidence of such a trend. Many indicators point in the opposite direction, suggesting marine demand may be more subdued than expected.

While oil demand in general is imperfectly measured and understood, that from the shipping sector is even more elusive.[7] Since marine bunkers are, by definition, consumed at sea, countries do not normally include them in their estimates of domestic oil demand. This explains the unusual level of uncertainty attached to global bunker demand data. Even the International Energy Agency (IEA), the global benchmark for energy statistics, shows some inconsistency in this matter. In its medium-term oil market forecast, *Oil 2017*, it estimates the bunker market at 4.2 million barrels per day (bpd), or roughly 4% of global oil demand. That includes 3.4 million bpd of HSFO and 0.8 million bpd of lower-sulfur MGO used in ECAs. In its long-term *World Energy Outlook*, however, it pegs total bunker demand at 3.8 million bpd, including 3.2 million bpd and 0.6 million bpd of HSFO and MGO, respectively.[8] The IMO itself goes by a higher estimate of 300 million tons (approximately 5.5 million bpd) for 2012 and a baseline projection of 320 million ton (5.9 million bpd) for 2020.[9] Uncertainty notwithstanding, the IEA's 4.2 million bpd estimate likely provides an acceptable order of magnitude, but its forecast of 1.9% average annual growth in total fuel demand for international shipping from 2015 to 2040, including 1.2% for oil, looks off the mark. While seemingly low compared to the IEA's projection of 3.6% annual growth in shipping activity, it far exceeds its estimate of total oil demand growth (0.5%) for the same period.[10] Yet recent evidence suggests that efficiency gains in shipping have far outpaced those in other sectors of the economy, and more gains seem likely in the future.

While country-level bunker statistics can be of questionable quality, company-level data, when available, do shed light on consumption trends. Given the ownership structure of the shipping industry, these are not always forthcoming. Chinese companies and privately-owned firms loom large in the sector and tend closely to guard this type of information. Others, however, do make disclosures. Public releases from shipping companies and other anecdotal information suggest that a combination of positive factors, such as fuel efficiency gains, and negative ones, such as slowing world trade growth, have taken a toll on demand.[11] These also suggest the sector's oil consumption might be set for further declines or very slow growth. Like many other oil-intensive industries, marine shipping has slashed its fuel requirements in recent years, in a multipronged effort to reduce its exposure to oil-price risk and to shore up profitability. This includes cyclical, reversible trends, such as slow steaming, a fuel-saving practice first popularized by very large crude carriers (VLCCs) in 1974–1976 and reintroduced during the oil price rally of 2002–2008. It also includes longer-lasting, more structural changes that have unlocked substantial gains in fuel efficiency. The impact of those trends has been compounded, at the margin, by the first attempts at fuel diversification away from oil in the marine sector. We review a few of these demand-inhibiting factors below.

2.1. Slow steaming

The shipping industry was hit hard by the 2002–2008 oil rally, which hurt its profit margins despite robust shipping demand. Maersk, the world's largest container carrier company, led the industry in systematizing slow steaming, the practice of deliberately lowering the speed of a ship to reduce fuel costs. While oil prices eased back in late 2008–2009, and again since mid-2014, freight markets failed to rebound, pressured as they were by substantial fleet overcapacity in the wake of new builds and slowing trade growth. While the cost benefits of slow steaming are proportional to oil prices and may seem less compelling in a lower oil-price environment, the practice offers the extra advantage, when shipping markets are oversupplied, of mopping up excess capacity. That helped perpetuate it through the recent ups and downs of freight rates and oil prices.

Not all sectors or routes are equally prone to slow steaming. Container carriers, which account for roughly one-third of the global fleet, are best suited to the practice, as they have the greatest speed variability. Bulk carriers and oil tankers can also benefit, however, and have adopted the practice.[12] Industry sources indicate that recent market conditions in certain trade routes have particularly favored extensive lay-ups and slow steaming to mop up excess capacity. Maersk has argued that slow steaming not only saves energy but also reduces carbon emissions and increases marine transport reliability by reducing bottlenecks at terminals.[13] Some sources, while conceding that there are overall improvements in efficiency, point to barriers affecting the

[7] Bunker fuels are exports that do not get imported into any country and, thus, tend to fall into the cracks of official statistics.

[8] International Energy Agency, *Oil 2017*, 105; International Energy Agency, *World Energy Outlook 2016,* 117–118. The two reports seem to use different reference years. *Oil 2017* uses 2016, while the *World Energy Outlook* uses 2015. A one-year difference, however, does not explain the gap between the estimates.

[9] Edmund Hughes, "0.50% Sulfur Limit for Fuel Oil Used by Ships" (presentation, CGEP-AEP-RUSI Roundtable, London, February 20, 2017).

[10] International Energy Agency, *World Energy Outlook 2016*, pp. 118–119.

[11] In keeping with the nature of their business model, container carriers tend to be more forthcoming with information about their fuel use than other shipping companies. Hapag-Lloyd and Maersk provide detailed information about their fuel consumption in quarterly and/or annual reports. Several of their reports are referenced below.

[12] According to industry estimates, tankers and bulk carriers together account for more than 100 million tons per year of HSFO demand, or roughly two-thirds of the market. That's compared to roughly 55 million tons per year consumed by a global fleet of about 5500 container carriers.

[13] "Slow Steaming Here to Stay," *A.P. Moller -Maersk*, September 1, 2010, http://www.maersk.com/en/the-maersk-group/press-room/press-release-archive/2010/9/slow-steaming-here-to-stay. See also "Maersk Line: Moving Away from Slow-Steaming Would Require a Fundamental Change to the Network," *Ship and Bunkers*, January 22, 2015, https://shipandbunker.com/news/world/223738-maersk-line-moving-away-from-slow-steaming-would-require-a-fundamental-change-to-the-network.

implementation of efficiency measures and thus limiting efficiency gains (Vierth et al., 2015; Winnes et al., 2015; Rehmatulla et al., 2017).

A 2013 study that sought to estimate the costs and benefits of slow steaming under various volume and fuel-price assumptions found that the practice 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%, and it remained optimal for future volumes under a wide range of fuel prices (Maloni et al., 2013). Despite widespread adoption and signs of institutionalization in recent years, however, experience suggests slow steaming is likely the most transient of factors yielding to lower fuel consumption, and it may remain subject to reversal, depending on market conditions.

2.2. Industry consolidation and fleet optimization

Other factors reining in oil demand for marine transport reflect more permanent changes. Consolidation in the shipping industry, notably among container ships, has gained momentum since it began in the mid-1990s, unlocking vast fuel efficiencies. Years of relentless restructuring have achieved substantial economies of scale. There is more to come. According to a recent ranking by Alphaliner, a trade news service, the top five ocean carriers account for nearly 60% of the combined capacity of the top 100 carriers as measured in 20-foot equivalent units (TEUs). The top 10 make up a full 75% of the pool.[14] The industry has gone through three successive consolidation waves. The first two waves, in 1996–2000 and 2005–2008, raised the top five companies' market share from an estimated 27–43%. The current wave, started in 2015, has lasted into 2018, further lifting their share to a projected 57% (66% for long-haul trades). In the last two years, eight of the top twenty players have been eliminated from the industry roster.[15] Consolidation has brought with it improvements in fleet management and substantial fuel savings. Maersk credits "network rationalization," one of the main tools in its "cost toolbox," for unlocking "significant cost reductions".[16]

Compounding the impact of mergers, container carriers have also been pooling their fleets into global alliances, akin to those of airliners, to share vessels and further rationalize operations. That secondary level of consolidation has allowed them to extend geographic coverage and service range and leverage their assets more effectively. A tertiary form of consolidation is even occurring at the pool level. In early 2017, the four leading ocean-carrier alliances were cut down to three. The 2M Alliance, Ocean Alliance, and THE Alliance now represent a combined 77% of global container capacity and 96% of East-West trade container capacity.[17] "Network improvements" and "optimization" allowed Maersk to improve bunker fuel efficiency by 1.8% year on year in the first quarter of 2017, the company reported, following up on a 2.2% improvement in 2016.[18,19]

2.3. Vessel design and economies of scale

Fuel savings achieved through economies of scale and advances in fleet management have been recently compounded by increases in vessel size. Ever larger carrier ships enable substantial efficiency gains. The race for size took off in earnest in 2013, when Maersk launched its Triple E class of container ships of more than 18,000 twenty foot equivalent unit (TEU).[20] China Shipping Container Lines (CSCL, now China COSCO) followed suit with the 19,100-TEU *CSCL Globe*, launched in November 2014, along with four sister ships.[21] Then came Mediterranean Shipping Company (MSC) with the 19,224-TEU *MSC Oscar*, christened in January 2015, along with sister ships *MSC Zoe* and *MSC Oliver*. *MOL Triumph* has since breached the 20,000 TEU mark, and a recent delivery was over 21,000 TEUs. These vessels set records not only for size but also for fuel efficiency. The Triple E name refers to the three principles of economy of scale, energy efficiency, and environmental excellence. Announcing the launch of the *Globe*, CSCL likewise touted its fuel efficiency and lower CO_2 emissions and noise.

Shipping companies that disclose their fuel consumption – admittedly a minority in a notoriously opaque industry – confirm sizeable reductions in fuel intensity. Hapag-Lloyd boasted about an 8.4% year-on-year drop in bunker consumption to 0.43 metric tons (MT) per TEU for the first quarter of 2017, credited in part to its large vessels. Despite higher shipping volumes, total bunker use fell by 2.2% year-on-year in the first quarter, to 803,000 MT, and by 6.3% in 2016, extending earlier drops.[22] The company attributed the latter decline to "the use of larger and more efficient ships as well as the optimization of the deployed fleet and global services network".[23] Hapag-Lloyd may be something of an outlier, but other shipping companies feel the same pressures.[24] The bottom line is that the top shipping companies have been using less and less fuel even as they have kept increasing their market share and shipping volumes. Given continued industry consolidation, further reductions in fuel use are likely.

2.4. Shorter routes

Changes in sea lanes are also saving shippers some fuel. Since its expansion, completed in June 2016, the Panama Canal can accommodate not only more vessels, but also larger ones. The project doubled the canal's capacity by widening and deepening the lanes and locks and adding a new lane. Whereas the largest ships that could previously make the passage were 5,000-TEU Panamaxes, the expanded canal can now accommodate so-called neoPanamaxes, or new Panamax ships, of 14,000-TEU capacity.

As global warming melts Arctic sea ice, shipping routes eventually will open over the North Pole and other previously impassable areas, which could greatly reduce travel times for long-haul shipping. Parts of the Arctic are opening up, resulting for example in more fishing activity (Eguíluz et al., 2016). The prevailing view, however, is that this remains a relatively distant prospect and is unlikely to occur on a large

[14] "Alphaliner TOP 100," *Alphaliner,* accessed July 3, 2017, https://alphaliner.axsmarine.com/PublicTop100/.

[15] "Maersk—The New Direction" *A.P. Moller – Maersk*, 13. Mergers and acquisitions proceeded at a brisk pace in 2016. This included the announcement or completion of several large deals, such as the merger of China Ocean Shipping Co. and China Shipping Group, now China COSCO, China's biggest shipping company and fourth on the Alphaliner list; Hapag-Lloyd AG and United Arab Shipping Co.; CMA CGM and Neptune Orient Lines (NOL) Singapore; and Maersk and Hamburg Sued. *Q4 – FY 2016 Investor Report,* (Hapag-Lloyd AG, March 24, 2017), 7, accessed July 3, 2017, https://www.hapag-lloyd.com/content/dam/website/downloads/pdf/HLAG_Investor_Report_FY_2016.pdf. In July 2017, Cosco also agreed to acquire smaller rival Orient Overseas (International Ltd.). See the *Wall Street Journal* from July 10, 2017.

[16] "Maersk—The New Direction," 34.

[17] N. Poskus, "What the New Ocean Carrier Alliances Mean for Your Freight," *Flexport.com*, accessed July 3, 2017, https://www.flexport.com/blog/what-are-ocean-alliances/.

[18] "Maersk Q1 2017 report – 11 May 2017 conference call," (*Maersk*, online PowerPoint presentation, p. 9, accessed July 3, 2017, http://files.shareholder.com/downloads/ABEA-3GG91Y/4890832430×0x942439/74BCF21F-9B4B-4FAC-82E6-7F1B08AC02D1/Maersk_Q1_2017_Presentation.pdf).

[19] *Annual Report 2016* (Copenhagen: A.P. Moller – Maersk, 2017), 13.

[20] "The World's Largest Ship," *Maersk.com*, accessed July 3, 2017, http://www.maersk.com/en/hardware/triple-e.

[21] N. Cabrera, "The Largest Container Ships in the World: *CSCL Globe*, *MSC Oscar*," *Ship Lilly*, December 26, 2014, http://www.shiplilly.com/blog/largest-ships-world-cscl-globe-msc-oscar/.

[22] *Q1 2017 Investor Report (*Hapag-Lloyd AG, May 12, 2017), 7 and 12, downloaded July 3, 2017, https://www.hapag-lloyd.com/en/ir.html.

[23] *Id.*, 11–12.

[24] Although the company's investment reports focus on vessel size as a driver of efficiency gains, slow steaming might have played an important role.

scale until midcentury, not only because of the harsh conditions but also because the lack of supporting infrastructure makes established routes often the preferred ones (Lasserre and Pelletier, 2011).

2.5. Digitalization

Looking forward, digitalization is poised to redefine marine transportation just as it is transforming personal mobility. Digitalization promises to take fleet optimization to a new level and unlock new fuel economies. After being collected from flowmeters, control and alarm systems, sensors, and time stamps, fleet operation data are run through an analytics engine that lets the company unlock new fuel efficiencies, shorten port stays (a cost center), and improve network design. "Advanced analytics opens up a whole new playground of opportunities," claims Maersk, including "real time network optimization for bunker savings," predictive repairs, cargo mix optimization, and more.[25]

Digitalization saves fuel in at least two ways: by optimizing engine performance (notably, but not exclusively, through predictive repairs) and by optimizing fleet management. Combined with industry consolidation and the pooling of fleets into ever-expanding global alliances, digitalization sets the stage for the "Uberization" of marine transport. In this system, multiple operators pool their fleet capacities and leverage their vessels in the most cost-effective and fuel-efficient way.

2.6. Fuel switching

LNG has begun to challenge oil's monopoly on marine transportation, thanks, on the supply side, to a newfound abundance of natural gas and advances in liquefaction technology and capacity, and, on the demand front, to (often local) environmental policies aimed at improving air quality. Battery-powered and hybrid ships are still in the future, but their prospects are brightening. The establishment of relatively stringent sulfur emission standards in ECA's, as of January 1, 2015, has led to fuel switching to lower-sulfur oil bunkers in parts of Europe, North America, and Asia, as well as the first forays into LNG bunkers. As the distribution infrastructure required to use LNG as bunker fuel remains in its infancy, LNG penetration has until recently been limited to discrete segments of the fleet in ECAs, such as short-haul Scandinavian ferry lines or barges in Chinese waterways. As of 2018, there were an estimated 122 ships reportedly fueled by LNG, compared to a total oceangoing fleet estimated at 45,000 vessels. That number is expected to pass the 200 mark by 2020. Most LNG-fueled vessels are expected to remain dedicated to specific routes, including several cruise liners and Aframax tankers plying the North Sea–Rotterdam trade.[26] Recent LNG supply deals announced by Shell's marine division fall into that category: these include an agreement with Russian shipping company Sovcomflot to supply four new LNG-powered Aframax crude tankers, the first of their kind, and another with cruise operator Carnival to supply two new ships due to start sailing in northwest Europe and the Mediterranean in 2019.[27] These cruise vessels will also be among the first of their kind to run on LNG.[28] More recently, however, privately-held CMA CGM, one of the world's largest container carriers, signed a landmark deal for nine LNG-powered, 22,000-TEU ships to be delivered in 2020.[29] Shortly thereafter, it followed up with a 10-year, 300,000 t/year LNG supply deal with Total Marine Fuels Global Solutions.[30] This high-profile deal took LNG bunkering to a new level and reportedly triggered a groundswell of interest in LNG bunkering from shipping companies.[31] In February 2017, CMA CGM agreed with Total to "examine the most environmentally responsible propulsion solutions to meet the International Maritime Organization's 2020 implementation date for new sulfur regulations."

Electric ship engines are being developed but are not generally considered a viable option in the near term. They might very well play a role in future, though. Norwegian ferry company Norled AS, shipyard Fjellstrand, and Siemens AS have developed the world's first 100% battery-powered passenger and car ferry, the *MF Ampere Ferry*.[32] Hybrid diesel and battery-powered vessels are also under development (see Lan et al., 2015).[33]

3. Will desulfurization reduce oil use in marine transport?

The desulfurization of the marine sector is as environmentally urgent as technically daunting. Like aviation, the shipping sector has long been relatively exempted from the more stringent air-quality regulations common to the rest of the oil market. Air emission considerations, such as those that led to the adoption of MGO as fuel in so-called Emission Control Areas (ECAs) in parts of Europe, North America and the Chinese coastline, or even those that supported switching to LNG in some niche market segments, have remained exceptions. The sulfur cap for MGO is 0.1% in US and European ECAs (since January 2015) and 0.3% in China's unilateral ECAs. Elsewhere, HSFO is the fuel of choice. At 3.5%, its sulfur content is 2300 to 3500 times higher than that of on-road diesel burned by most cars and trucks, which is capped at 15 ppm (ppm), or 0.0015% in the United States. It's even less (typically 10 ppm) in the European Union and China.[34] A single container carrier, therefore, emits as much SOx as millions of diesel cars.[35] That makes the

[25] "Maersk—The New Direction" *A.P. Moller – Maersk*, 38 and 56–61.

[26] Anna Shiryaevskaya and Rakteem Katakey, "Oil Tankers to Cruise Ships Fueled by LNG Offer Hope on Gas Glut," *Bloomberg News*, April 25, 2017, https://www.bloomberg.com/news/articles/2017–04-25/oil-tankers-to-cruise-ships-fueled-by-lng-offer-hope-on-gas-glut. New LNG vessels on order reportedly include seven cruise lines from Carnival and four Aframax tankers from Russia's largest tanker operator, Sovcomflot. See also Mike Corkhill, "The World's LNG-Fueled Ships on Order, 2017," *LNG World Shipping*, April 24, 2017, http://www.lngworldshipping.com/news/view,the-worlds-lngfuelled-ships-on-order-2017_47089.htm.

[27] These four dual-fueled tankers will ply routes in the Baltic Sea and Northern Europe. https://www.shell.com/energy-and-innovation/natural-gas/lng-for-transport/news-and-media-releases/shell-to-fuel-worlds-first-lng-powered-crude-oil-tanker.html.

[28] As of late 2017, Carnival's AIDA brand already operated the first cruise ship in the world to use LNG as a fuel when in port, the *AIDAprima*. In addition, Carnival Corporation commissioned a total of seven LNG-powered cruise ships for four of its 10 cruise brands by 2022, including two for AIDA Cruises, two for Costa Cruises, one for P&O Cruises UK and the two ships for Carnival Cruise Line. *The Maritime Executive*, November 9, 2017, https://www.maritime-executive.com/article/shells-lng-bunker-barge-will-fuel-giant-cruise-ships#gs.RHyy5k0.

[29] https://www.cma-cgm.com/local/south-africa/news/72/cma-cgm-group-has-chosen-to-equip-its-nine-giant-ships-of-22–000-teu-with-engines-powered-by-lng-.

[30] http://www.cma-cgm.com/news/1841/strategic-agreement-between-total-and-cma-cgm-on-liquefied-natural-gas-fuel-supply-for-cma-cgm-new-build-container-ships.

[31] Authors interviews with industry participants, February 2018.

[32] See "Ampere Ferry: World's First All-Electric Car Ferry," *Corvus Energy*, http://corvusenergy.com/marine-project/mf-ampere-ferry/.

[33] "The Marine Hybrid Battery Is Here," *Corvus Energy*, July 1, 2014, http://corvusenergy.com/the-marine-hybrid-battery-is-here/.

[34] Sulfur content is more commonly expressed in parts per million (ppm) in the case of low-sulfur fuels. Expressed in this unit, 0.0015% equals 15 ppm, and 0.001% is equivalent to 10 ppm.

[35] According to the International Gas Union, one large container ship at sea using 3% S bunker fuel emits as much SOx as 50 million diesel-burning cars. See International Gas Union, *Enabling Clean Marine Transport*, March 2017, 4 (IGU.org, accessed July 3, 2017, http://www.igu.org/sites/default/files/node-document-field_file/IGU_A4_CleanMarineTransport_Final%20March%202017_3.pdf). References provided for this estimate include Monitoring Atmospheric Composition and Climate (MACC) II, *Report on the Evaluation of Ship Emissions and Harmonized Dataset*, July 2014 (accessed July 2, 2017, http://www.gmes-

shipping industry one of the world's top sources of SOx by far, as well as a major source of NOx and GHG emissions.[36] As winds carry marine emissions inland, ships have been an important cause of premature human deaths and respiratory symptoms in coastal regions outside of ECAs.[37] From the megacities of China's east coast and India's west coast to those of Africa and Latin America, human population is increasingly concentrated in large coastal metropoles with bustling port facilities. These urban habitats are disproportionately exposed to health risks from marine emissions.

While technical and cost factors have been working, as noted above, to cut the volumes of oil fuels burned by ships, the IMO 2020 standards set out to reduce their sulfur content – thus adding qualitative improvements to the quantitative shifts in the industry's footprint. The new rules go a long way toward bridging the gap between air emission standards on land and at sea. The SOx content of air emissions from ships outside ECAs will drop to a level corresponding to a bunker sulfur cap of 0.5%. That's still higher than diesel but dramatically lower than previous levels. As overdue and urgently needed as these tighter standards may be, however, they also represent a highly impactful and potentially disruptive plunge.

Given the scope of the change in SOx emission standards, one could have expected the new rules to accelerate a shift away from oil in marine transportation. Being relatively sulfur-free and increasingly abundant, LNG as bunker fuel would seem particularly attractive and poised to greatly benefit from the IMO 2020 rules, as an alternative to higher-sulfur, oil-based fuels. Yet, as noted, a takeoff in LNG bunkering would carry the seeds of its own undoing through the price increase that would presumably result for a large step gain in overall LNG demand. LNG bunkering could also quickly bounce against distribution infrastructure limits. While widespread adoption on LNG bunkering would require a large LNG bunkering distribution network, large-scale investment in such a network would also be predicated on a critical mass of users – a classic chicken and egg problem.

In practice, thus, there is still a lot of daylight between the scope of adjustment called for by the new IMO rules and the changes that are occurring. Ten years after the regulations were introduced, LNG adoption rates remain low in the marine sector. Market interest has only recently started to pick up, practically from scratch, and the impact of the new rules has remained so far limited. Despite some growth in the order book of LNG-powered ships, and despite the early steps taken by major ports and bunker providers to offer LNG bunkering services, natural gas may not initially be the first choice for shippers to meet the new emission standards. Broadly speaking, industry participants have only slowly provided evidence that they have taken steps to comply with the rules, prompting analysts to worry that time is running out to achieve the regulations' objective.

In its bid to foster cleaner bunkers, the IMO has picked performance standards (“obligations of result”) over technical ones (“obligations of conduct”). It is not the first time the regulator has opted to remain agnostic as to the path chosen by shippers to achieve the target. It is easy to see why. Technical standards “pick a winner” and run the risk of discouraging innovation by mandating the use of a preferred technology. In contrast, performance standards ostensibly leave it up to market participants to chart their paths to a desired outcome. Performance standards are widely seen as promoting market innovation and minimizing lock-in risks. Market participants are effectively incentivized to innovate and come up with new technological options in their bids to comply at the lowest possible cost. On the flip side, performance standards have a recognized downside: they are, by nature, notoriously difficult to enforce.[38] The IMO sulfur cap meets the definition of a performance standard in that it specifies an intended outcome, or *result*—the amount of sulfur oxide that ships are allowed to release into the air—but leaves the *conduct*—how shippers meet that goal—up to them.

Although IMO policy is, on paper, technologically agnostic, this neutrality is only apparent, however. The accumulated uncertainty, exacerbated by the very technology-neutrality of IMO policy, effectively favors the option that requires the least planning and up-front expenditure from shippers. Although refiners are not directly targeted by the rules, we believe this puts the onus on them, who will have to cater to demand, and anticipate to the best of their ability changes therein. We now discuss those possible consequences in more detail.

4. Consequences for refiners

While for shippers, lower-sulfur fuels may be the low-cost, “easy” way to meet the coming IMO sulfur standards, the prospect of a sudden migration of shipping demand to lower-sulfur fuels appears, for the refining industry, as a tall order. Shippers, by relying on the “default” option, effectively shift the burden of compliance onto fuel suppliers.

For the latter, the problem is twofold: a potential collapse in demand for HSFO, a byproduct of refining for which there are few other uses, and a surge in demand for lower-sulfur fuels, of which there is limited supply. Most analysts reckon that the new shipping fuel of choice will be MGO, a middle distillate akin to diesel (albeit with a higher sulfur content). The concern is then that with diesel demand from other sectors also widely expected to boom, refiners might not be

(*footnote continued*)
atmosphere.eu/documents/maccii/deliverables/emi/MACCII_EMI_DEL_D_22.2.final.pdf) and Olaf Merk, *Shipping Emissions in Ports,* International Transport Forum Discussion Paper, Paris, OECD, December 1, 2014 (accessed July 3, 2017, http://dx.doi.org/10.1787/5jrw1ktc83r1-en). A back-of-the-envelope effort to replicate this calculation yielded significantly lower—albeit still staggering—results. An average size (8000 TEU) container ship running on 3.5% S HSFO (higher sulfur than in the IGU case) releases as much sulfur oxide (SOx) as 9.9 million small passenger cars running on 15 ppm sulfur diesel or 14.9 million cars using 10 ppm sulfur diesel. This assumes that the ship consumes about 225 tons of fuel per day at a speed of 24 knots, with a conversion rate of 1009 liters per ton, and it assumes the car consumes 5 liters per 100 kilometers.

[36] According to the International Energy Agency international shipping activity in 2015 emitted 8.2 million tons of sulfur dioxide (SO_2), or 10% of global energy-related SO_2 emissions. The IEA noted that the relative share of shipping is much higher in coastal areas, and Hong Kong reached 44% of SO_2 emissions before the adoption of corrective measures (International Energy Agency, *World Energy Outlook 2016,* 120). Other estimates are higher. For example, the Organization for Economic Cooperation and Development (OECD) estimates that ships generate “approximately 5–10% of all SO_2 anthropogenic emissions”—not just energy-related SO_2 emissions—at a global level. The OECD also notes that these shipping emissions “can represent a large share of total emissions in port-cities and have important health impacts.” See *Reducing Sulfur Emissions from Ships: The Impact of International Regulations*, OECD Corporate Partnership Board Report, International Transport Forum, May 9, 2016, 10 (accessed July 3, 2017, https://www.itf-oecd.org/sites/default/files/docs/sulfur-emissions-shipping.pdf). According to the IMO, during 2007–2012, shipping on average accounted for about 3.1% of annual global CO_2 and 2.8% of annual GHG emissions on a CO_2-equivbalient basis, and international shipping accounted for about 2.6% and 2.4% of CO_2 and GHG emissions, respectively. “Third IMO GHG Study 2014,” *IMO*, http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Greenhouse-Gas-Studies-2014.aspx). IEA estimates that the shipping sector accounts for around 2% of global energy-related CO_2 emissions. That's equivalent to the emissions of Indonesia and Malaysia combined (International Energy Agency, *World Energy Outlook 2016,* 118).

[37] US Environmental Protection Agency, *National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports*, Office of Transportation Air Quality, 2016, (EPA-420-R-16-011).

[38] See Daniel Bodansky, *The Art and Craft of International Environmental Law* (Cambridge, Massachussetts and London: Harvard University Press, 2010), 76–79, and Scott Barrett, *Why Cooperate? The Incentive to Supply Global Public Goods* (Oxford: Oxford University Press, 2007), 161–162.

up to the task without substantial investment in processing capacity. In addition, incremental emissions rules (specifically for carbon) cloud the longevity of the investment window that refiners look at.

A diesel shortfall, if it were to occur, could be disruptive. Diesel, or more generically middle distillate, is the most versatile of oil products, used in many applications, from trucking and railroads to passenger vehicles, power generation, agriculture, space heating, and various industrial uses, as well as shipping. A diesel rally could quickly spread across geographies and spheres of economic activity. Surging diesel demand was widely associated with the 2008 oil rally, when the price of front-month light, sweet crude futures reached a record $147/barrel at the NYMEX.[39] As the theory goes, an imbalance in diesel supply and demand put a price premium on light, sweet crude benchmarks such as West Texas Intermediate (WTI) and North Sea Brent, which both have a high yield of diesel and other light products.[40]

Yet just as shippers show few signs of having taken concrete steps to prepare for the IMO rules, the same may be said of the refining industry. With a few notable exceptions, most refiners, unsure of the shipping industry's response, seem to have taken a wait-and-see approach to the new standards. This has led many analysts to draw analogies with the 2008 rally and recall that another, albeit far more dragged out, desulfurization campaign, that of road diesel, had helped tighten diesel markets and send oil prices through the roof a decade ago.

While the challenge for the refining industry is undeniable, such fears overlook three key factors. First, forecasts of diesel demand are highly uncertain. The desulfurization of road diesel in the 2000s occurred against a backdrop of surging diesel demand from China and other emerging economies, the effects of which were compounded by the dieselization of the European car fleet. In contrast, current expectations of robust growth for trucking and other uses may well be way overstated—so shippers may not have to compete as hard for finite distillate supply. In China, for example, the production of large LNG trucks is booming, as the central government curbs diesel demand to improve the local air quality in urban areas. Second, expectations of surging MGO demand from the marine sector assume that shippers that do not switch to LNG will be largely limited to a choice between two established refined products, HSFO and MGO. While today those may be the main fuels on the menu, that might not be the case in the future. Given the high viscosity requirements of large ship engines, most future bunker fuels are more likely to be new LSFO hybrids. Producing these new fuels will not put as much stress on the distillate pool as analysts fear, but will likely require large volumes of vacuum gasoil (VGO), an intermediate feedstock that is an important building block of European gasoline production. Gasoline, rather than diesel, could thus be the product that comes short. Finally, forecasts of a tight diesel market give short shift to shippers' option of last resort: noncompliance. Unattractive as it might seem, noncompliance may play an important role in the shipping industry's response to the new rules—especially in view of the IMO's absence of enforcement capability on the high seas.

4.1. A replay of 2008?

Although bunkers only account for an estimated 4–7% of global oil demand, their importance for refiners as the world's largest sink for the "bottom of the barrel," the low-value, high-sulfur byproducts of the refining process, far exceeds their share of the overall market. Changes in bunker fuel markets could thus have far-reaching impacts on the "downstream" sector as a whole, precipitating the demise of some of the less competitive European refineries and accelerating the restructuring of the global refining industry. Among other effects, this could make Europe more dependent on refined-product imports and further enhance the role of trading companies in global product supply, with potential implications for energy security and oil price volatility.[41]

Argus Media, a specialized energy communications and analysis firm, reckons that marine bunkers alone account for nearly half (47%) of the world's end-user demand for that increasingly unwanted product, with power generation a distant second (32%), followed by other industrial uses (20%).[42] Stationary demand for residual fuel oil has been dwindling as power stations increasingly turn to natural gas, renewable sources, or even coal instead of HSFO, supplemented in many emerging markets by the widespread use of diesel-fired backup generators. This has only served to increase the importance of bunker fuels as the last remaining sink for heavy products. Now that sink too is at risk.

Many analysts reckon that the new IMO rules will drastically cut residual fuel oil use from the marine sector, with HSFO consumption seen down by more than 75% to perhaps just 500,000 bpd to be burned on scrubber-fitted vessels, leaving up to 2.5 million bpd of demand to migrate to lower-sulfur fuel markets (IEA, 2018). Of that amount, analysts expect 500,000 bpd to 600,000 bpd at most to be LSFO, and the rest MGO. Such a large-scale shift away from HSFO would leave much of the refining industry scrambling to find alternate outlets for high-sulfur fuels. Notional HSFO refining margins are usually negative, giving refiners an incentive to invest in conversion capacity to cut their HSFO yields. Significant erosion of the HSFO market would widen that negative spread. Not all refineries can muster the capital to upgrade, however. Some of the more challenged, smaller, less competitive refineries with high HSFO yields might not survive the test.

Conversely, analysts fear that surging low-sulfur fuel demand will put distillate production capacity to the test, in a replay of the 2008 oil rally. LSFO supply is seen as constrained by the limited availability of low-sulfur crude oil, which refiners can run to produce LSFO without sulfur removal.[43] That would leave MGO, which is produced from higher-sulfur crude but must usually go through a desulfurization unit, as the main option to meet the bunker specs. Just as LSFO supply will bump against feedstock constraints, hardware limits, notably in cracking and upgrading capacity, could cap MGO availability.

The IEA reckons that low-sulfur crude availability will cap production of compliant LSFO at about 500,000 to 600,000 bpd by 2020. Based on its bullish take on shipping requirements, it projects growth in MGO demand of up to 2.9 million bpd by 2020, adding to incremental diesel consumption forecasted at 1.9 million bpd. While middle distillate demand is thus projected to expand by a total of nearly 5 million bpd, refinery upgrades and expansions are seen boosting refinery throughputs by close to 4 million bpd—leaving the market short of diesel by roughly 1 million bpd. Expanding distillate production capacity beyond projects that are already underway would come at a steep

[39] Philip K. Verleger, in his weekly *Notes at the Margin* and other publications, was one of the first analysts to posit a connection between diesel desulfurization in the 2000s and the 2008 oil rally. Lawrence Eagles, then head of oil analysis for J. P. Morgan, and others followed suit. Salvatore Carollo picked up the argument in *Understanding Oil Prices: A Guide to What Drives the Price of Oil in Today's Markets*, Chichester, United Kingdom: Wiley, 2011.

[40] Low-sulfur, or "sweet," crude oil grades are expected to come under upward price pressure in the event of a run-up in demand for low-sulfur products because of their comparatively high yield of the latter. The sulfur content of residual fuel oil depends on that of the crude oil used as feedstock to produce it. Middle distillate coming out of a cracking unit will have a relatively low sulfur content and may be further desulfurized through a hydrotreating unit; however, sweet crude grades also have a higher yield of low-sulfur distillates.

[41] On the globalization of the refining industry and its effects on price volatility and energy security, see Halff, "The Impact of Refining Sector Changes on Patterns of Oil Product Trading," Oxford Energy Forum, Issue 92, May 2013, pp. 4–5.

[42] Argus. It is important to note, however, that residual fuel oil is widely used as feedstock for refinery conversion units. If fuel oil traded as feedstock were considered, bunker's share of the fuel oil market would be considerably lower.

[43] As noted above, LSFO is here understood to have a sulfur content of 0.5% or less.

cost and take too long anyway to be completed in time.[44]

A consensus of sorts appears to have coalesced around the forecast of an imbalance of this order of magnitude by 2020. That projected 1 million bpd distillate gap is fueling concerns about a diesel rally, which analysts fear could spread to low-sulfur crude oil grades like UK Brent or US benchmarks West Texas Intermediate (WTI, the base of the NYMEX/ICE crude future contract) and Light Louisiana Sweet (LLS). With ships seen competing head-on for finite distillate supplies with trucks, railroads, European motorists, farmers (agricultural pumps, tractors) and backup generators (ubiquitous in emerging markets), all these sectors could feel the pinch. Given that 80% of internationally traded goods are moved by ship, higher shipping costs could also spread to the broader economy at the margin via pass-through to manufacturers and consumers. The ripple effects could be disruptive.[45]

On paper, a disruptive run-up in diesel prices as demand bumps against capacity constraints could ultimately speed up a move away from oil in marine transport and incentivize investments in alternative fuel sources such as LNG bunkers. Expectations of such a disruptive market response rest on several questionable assumptions, however.

4.2. Uncertain diesel demand

While the oil market has a long record of supply/demand imbalances and price spikes, the history of forecasting errors and unexpected twists in oil demand patterns is even longer. Distillate markets may well tighten by 2020, but a full-blown supply crunch would be a worst-case scenario. As discussed above, projections of robust bunker fuel demand growth give short shrift to the efficiency gains already achieved by shippers and to the high potential for further improvements on the back of digitalization and industry consolidation. Forecasts of robust diesel demand growth from other sectors seem equally overstated.

Strong growth in diesel demand was a salient feature of the oil market of the 2000s, driven in part by the takeoff in the Chinese economy and the dieselization of the European automobile fleet. Gasoline markets were a mixed bag, with strong growth in emerging markets, led by China, but contraction in advanced economies, with signs of "peak demand" in the United States and fuel switching in Europe. Forecasters extrapolated from these trends to project robust growth in diesel consumption over the medium term, leading refiners to pile up investments in upgrading capacity to boost their diesel yields.

These trends appear to have stalled. Diesel demand from India and China in the first half of 2017 came in below expectations. Diesel has fallen out of style in Europe for automobile combustion engines in the wake of a 2012 World Health Organization study connecting particulate emissions from diesel exhaust to cancer. More recently, evidence of misreporting by diesel engine manufacturers about meeting emission standards—the so-called Volkswagen emission scandal—helped undermined policy support for the fuel. The scandal, also known as "emissionsgate" or "dieselgate," started in September 2015 when the US Environmental Protection Agency (EPA) found that German automaker Volkswagen Group had programmed some of its diesel engines to hide NOx emissions up to 40 times US limits, and charged it with violating the US Clean Air Act. Several European cities now plan to ban diesel for transportation, and it is likely that more will follow.

Following many years of steady growth, diesel consumption in major European economies, from France to the Netherlands, has already switched into reverse, while gasoline use is on the rebound. Diesel use in distributed power generation (backup generators, or gensets) in emerging countries is also facing headwinds, as alternatives, including natural gas and renewable energy, are being harnessed for electricity generation. Should forecasts of rapid electrification of the vehicle fleet in the United States and Europe come true, that too would undermine distillate markets. Meanwhile, the potential for efficiency improvement in the trucking sector, a leading center of diesel fuel use, is considerable.

4.3. Birth of a fuel

From the supply side of the equation, expectations of a distillate crunch also appear overstated. Such worries overplay the linkage between bunkers and distillate fuels and imply a "business as usual" segmentation of marine fuel markets into HSFO and MGO: forecasts assume shippers will simply shift from one to the other, changing the products' respective market shares but leaving their assays and the delineation between product categories essentially unchanged. In fact, refiners have more flexibility to maximize their yields of one type of fuel or another than they are given credit for. More importantly, the new IMO rules will likely move the boundaries that currently separate product categories and incentivize the emergence of new blended products. Shippers' and refiners' reluctance to invest in capital-intensive compliance options will put the onus of innovation on the blending side of the market—and in so doing may help entrench the role of oil in marine transport.

For several reasons, shippers are unlikely to be limited to a binary choice between HSFO and MGO. Already the global sulfur cap is spurring the emergence of new hybrid products combining the viscosity and lubricating properties of HSFO (required by most ship engines) and the low sulfur of MGO. Blending will likely play as large a role in producing those fuels as refining: some of the new LSFO products will be mixes of multiple components whose supply may not be constrained by upgrading or desulfurizing capacity.

The preference for new LSFO blends reflects in part the challenge of using MGO in large vessels whose engines call for fuels with higher viscosity than MGO can provide. MGO's lubricating properties, which are substantially different from those of HSFO, also require a corresponding adjustment in lubricating oils. This can be tricky. The switch to MGO has reportedly already contributed to collisions and other minor accidents due to engine failures or a lack of immediate engine response.[46]

Suppliers in some of the larger bunkering centers have already started offering new LSFO hybrids. Anecdotal evidence shows that shipping companies have been increasingly adopting this new bunker fuel grade.[47] Hapag-Lloyd's fuel usage here too is a case in point. In addition to its fuel consumption, its earnings reports have long provided details about its fuel mix, including the split between what it labels "marine fuel oil" (MFO) and "marine diesel oil" (MDO), a product akin to MGO. Recently it has started breaking down MFO use into low- and high-sulfur categories. Consumption of both high-sulfur MFO (HSFO) and MDO edged down in 2016, in line with a steep decline in overall bunker use, but that of low-sulfur MFO, or LSFO, bucked the trend, up by a steep 130%, lifting its share of the overall fuel mix by

[44] HSFO cannot simply be run through a hydrotreater for desulfurization, as it will cake up the catalyst. Increasing MGO supply requires upgrading capacity (in the form of hydrocracking or fluid catalytic cracking units) to raise gasoil yields. If needed, the gasoil can them be hydrotreated to reduce its sulfur content, though coming out of a hydrocracker, the sulfur content will be relatively low. Capacity upgrade projects typically have a lead time of up to six years, including two years to design and bid the units and another three to four to build them. Costs run up in the billions of dollars.

[45] Economic literature has highlighted the importance of transport costs in trade, access to markets, and per capita income. Fifteen years ago, World Bank economists found that "for most Latin American countries, transport costs are a greater barrier to U.S. markets than import tariffs." Ximena Clark, David Dollar, and Alejandro Micco (February 2002): "Maritime Transport Costs and Port Efficiency," World Bank Policy Working Paper 2781.

[46] Communication from industry source.

[47] Shell is, as noted, a case in point.

four percentage points year-on-year to 7%.[48]

It seems unlikely that LSFO production capacity will be as limited by refining constraints or crude oil availability as some projections suggest. Supply will come in part from blending vacuum gas oil (VGO), widely used in European refineries as intermediate feedstock for gasoline production.[49] A key source of VGO supply to Europe has historically been Russian refineries. Recent refinery upgrades have already reduced the availability of Russian VGO for export. VGO blending into the bunker pool by Russian refiners, which collectively have also been the world's leading bunker suppliers, will further constrain VGO shipments to Europe.

Thus, shifts in bunker fuel quality as a result of the IMO's new specs may affect gasoline supply more directly than they affect diesel supply. The shift will come, however, at a time when electric vehicles, compounding the effect of efficiency gains, are increasingly expected to take a toll on gasoline demand growth. Many analysts expect that the growing popularity of ride sharing and self-driven vehicles will speed up EV penetration, denting gasoline demand. Meanwhile, on the supply side, US gasoline production capacity is on the rise, thanks to high upgrading of US Gulf Coast refineries and rising supply of gasoline-rich tight oil.

4.4. Noncompliance

Finally, there is another factor that may at the margin reduce the risk of a surge in diesel demand when the IMO rules come into effect: the IMO's limited ability to enforce them.

No single entity has the authority, let alone the technical capacity, to carry out inspections on the high seas. The IMO lacks jurisdiction over the high seas and does not maintain a force capable of carrying out inspections. That leaves enforcement of the new rules in the hands of port states, which can check the records of the ships and bunker suppliers, as well as flag states—of which the top three are Panama, Liberia, and the Marshall Islands—that have neither the capacity nor perhaps the will to carry out inspections.[50]

While ships are required to keep records of bunker purchases, quality, and use, and port authorities can verify the bunker logs of incoming ships and require verification of bunker quality from bunker suppliers in the port, written records are generally not considered as reliable evidence of actual fuel consumption at sea. The most effective means of checking fuel use are flyovers and remote sensing of vessel emissions. These are costly enough to carry out in ECAs, let alone on the high seas. In 2018, rumors of insurance companies and banks taking on a part of the responsibility emerged – the argument being that insurances of companies that would get caught would be declared void – but collecting evidence seemingly continues to be a challenge.

Performance standards like the global sulfur cap are inherently challenging to enforce, compared to technical standards.[51] In the case of the sulfur cap, the challenge is particularly overwhelming, given the technical difficulty of tracking air emissions from a ship at sea and the complete lack of any credible enforcement authority on the high seas. Interestingly, the IMO in one earlier occasion had pointedly opted—-with great success—for a technical standard rather than a performance standard, when it required that oil tankers be double-hulled in support of its oil-spill prevention policy.[52] Despite ongoing efforts to address it, the problem of verifying compliance with the global SOx cap remains fundamentally unresolved.

5. Conclusion

We conclude that a more comprehensive environmental policy could have provided for clearer signposts to improve the GHG footprint of the shipping industry in the future. Lessons from the sulfur standards saga should be included as the IMO prepares for future GHG targets for the shipping sector, the first round of which is due to take effect in 2025.

The current IMO standards make continuity rather than significant change a more likely outcome of this policy intervention, spelling uncertainty for shippers, and emissions, for the years to come. However, structural changes in the shipping sector, combined with structural changes in fuel demand and the adaptability of most refiners, will likely prevent all too dramatic ripple effects of this policy as it is implemented in 2020.

Part of the challenge of implementing the IMO 2020 standards stems from the fact that shippers are effectively incentivized to wait until the last minute – or even until it is effectively too late – before taking practical steps to comply with the rules. The high cost of compliance means that early compliers are penalized rather than rewarded for their foresight and preparedness. One way to get around this problem in future – for instance, in deploying pending NOx and GHG regulations – would be to provide early compliers with incentives such as tax benefits or lower port fees to compensate for their costs.

In marine emissions as in other environmental matters, cities – and, in matters related to shipping, port cities – look set to play as large a role as states or international organizations, if not a larger one, in providing policy leadership. When it comes to enforcing the IMO rules, ports are clearly in the driver's seat. Although ports are myriads, international trade is, at the end of the day, largely concentrated among a relatively limited number of megahubs linked to major manufacturing and consuming centers. Port authorities in these mega cities ought to establish shared standards and best practices to ensure a level playing field and the consistent implementation of the IMO rules across regions and ship classes.

New technologies, including remote sensing via satellite, offer the promise of overcoming the lack of jurisdiction over the high seas to verify ships' fuel consumption not only at the ports of arrival or departure but during their voyage. The IMO should actively consider schemes to facilitate the deployment of these technologies, including cost-sharing among member states or port authorities, and thus greatly strengthen the credibility and effectiveness of IMO 2020 implementation and enforcement policies.

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[48] In percentage terms, the share of MDO in the company's overall fuel mix fell faster than that of HSFO. The former plunged from 12% to 9%, whereas the latter slid by a single percentage point, from 85% to 84%. In absolute terms, however, use of HSFO, given its much larger baseline share of the mix, fell faster, by 193,000 MT, compared to MDO, use of which contracted by 143,000 MT. *Q4 – FY 2016 Investor Report* (Hapag-Lloyd AG, March 24, 2017), 12, accessed July 3, 2017, https://www.hapag-lloyd.com/content/dam/website/downloads/pdf/HLAG_Investor_Report_FY_2016.pdf.

[49] The IMO's own commissioned study of fuel oil availability differs markedly from the prevalent view of industry analysts in predicting that LSFO, rather than MGO, will make up the bulk of IMO-compliant fuels. This may in part, but not entirely, reflect definitional differences. According to the IMO study, which is based on the expectation of relatively strong bunker demand growth overall, the refining industry will be able to supply enough LSFO to meet shipping demand under any of its different scenarios, although this will require significant shifts in bunker trade flows. See Halff, "IMO Roundtable," 2017, 3.

[50] "Flag State 2015: Top 10 Ship Registers," *Lloyd's List*, accessed July 3, 2017, https://www.lloydslist.com/ll/static/classified/article506818.ece/binary/Flag-worldfleet-final2.pdf.

[51] Bodansky, 76–79, and Barrett, 161–162.

[52] Barrett, 161–162. On the other hand, results-driven requirements have applied to oily-water separators and more recently ballast water treatment systems. In each case this has resulted in problems in meeting the results outcome required.

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