A MARKET MODEL FOR LNG TRADING AND LNG SHIPPING

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Introduction

LNG markets have significantly evolved over the last three years. In terms of volumes first with a rebound in LNG trades by 12% from 2018 to 2019 that followed an increase by 9% from 2017 to 2018. LNG markets have also moved towards commoditisation as more numerous buyers now trade smaller annual volumes, thus increasing the uncertainty on LNG demand. From the LNG shipping side, spot charter rates have been quite volatile in 2019, even if the 2018 pikes were not reached. As for LNG trading, changes in the global fleet size come with a shift towards more liquidity and the development of LNG shipping paper trades. Those major evolutions observed in LNG trading and LNG shipping have triggered higher complexity for market analysts and forecasters. This paper introduces a market modelling platform which is able to deal with such complexity.

1. The LNG and LNG shipping markets

Obviously, LNG shipping market and LNG market are closely linked. If LNG carriers actually move LNG molecules, one could say that, in terms of market development, LNG trades move the LNG shipping market. The evolution of LNG markets has impacted the LNG shipping market, not only because of the increase in LNG volumes traded but also because of structural changes in LNG markets.

Until mid 2000's, LNG trades were still dominated by point-to-point contracts, connecting a liquefaction project to a regasification terminal where an importer had booked capacities. From 2005, LNG portfolio players have gained weight in global LNG trade, becoming the link between producers aiming to secure long term revenues. Their share in LNG buyers' activity has evolved between 5% and 30% since 2005 (source IHS[2]). Playing an aggregating role for both supply and demand, portfolio players have contributed to the optimization of the LNG flows compared to the point-to-point contracts. This aggregating role has emerged as the growth in LNG markets has accelerated, especially since 2011.

Growth in global LNG trade has accelerated since 2016, reaching 10% on average per year between 2016 and 2019. This acceleration took place in long term growth patterns as the global LNG market has doubled since 2010. In 2020, there were in one hand 20 exporting countries summing 454 Mtpa of liquefaction capacity and 43 importing countries with representing 900 Mtpa of regasification capacity. It has to be compared to the 18 exporting countries (270 Mtpa) and 20 importing countries (600 Mtpa) in 2010[3].

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[1] The views expressed are those of the authors and do not necessarily reflect the views of TotalEnergies.

[2] LNG aggregators: A key vehicle for LNG trade flows, April 2017

[3] GIIGNL, The LNG Industry 2011

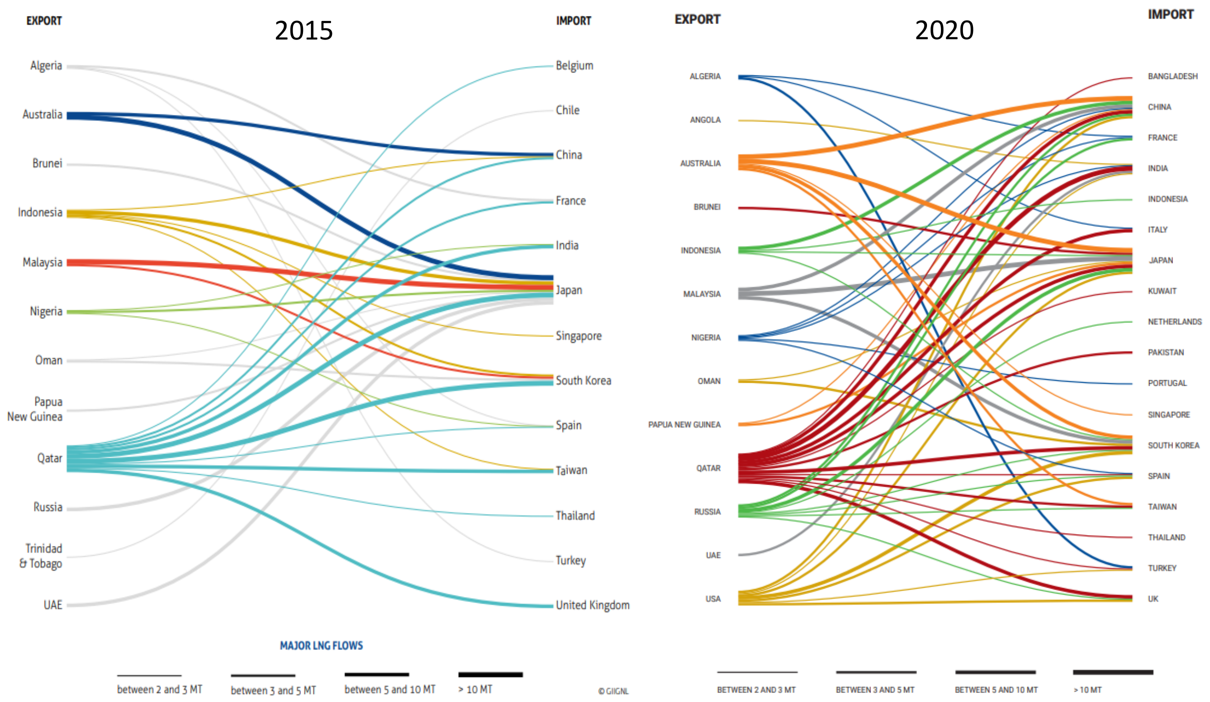

Figure 1: Chart LNG Flows 2015 versus 2020 (source GIIGNL)

The LNG trading schemes have also evolved with a growing portion of flexible volumes. By flexible, we mean volumes that can be easily diverted from their primary destination (at no or limited cost): it includes FOB volumes but also DES with locational flexibility. According to IEA[4], the share of destination-free contracts has been growing since 2015 to reach a share of 40% of total LNG delivered during 2018. Besides, the share of short term and spot volumes has been multiplied by 2 since 2010, reaching 40% in 2020[5].

Shipping has evolved accordingly to LNG markets. Shipping needs have evolved driven by two opposite forces. First, the multiplication of exporting and importing points has led to an increase in volumes and distances. Second, trades optimization allowed by more flexible contracts tend to lower the shipping needs. LNG shipping capacity has evolved accordingly to the LNG trades with high growth rates observed since 2010.

The last three years have witnessed a major increase in the fleet with 48 ships delivered in 2018, 39 ships in 2019 and 47 in 2020.

[4] IEA, Global Gas Global Gas Security Review 2019

[5] GIIGNL Annual Report 2021

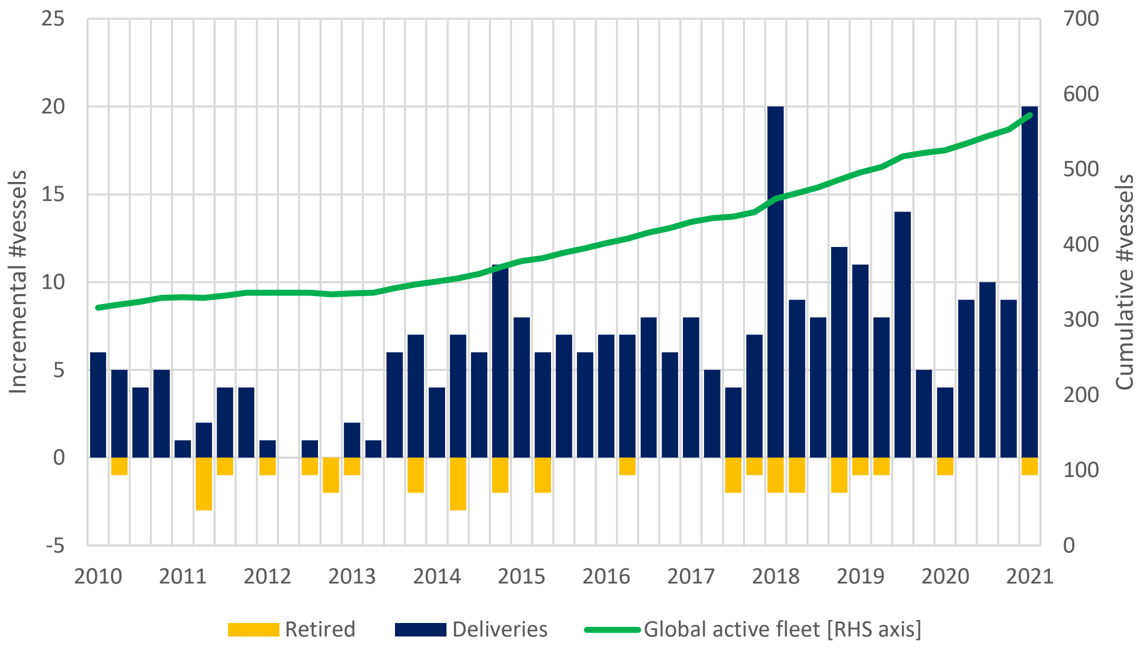

Figure 2: Estimated LNG carriers fleet quarterly development, vessels > 45 k cm

Nevertheless, in spite of this increase in available LNG carriers, the balance between shipping needs and capacity evolves from tight to loose. These cycles have been amplified as LNG demand patterns have also evolved towards more seasonality, driven by the increase of Chinese imports.

Spot charter rates have been quite volatile in 2019, even if the 2018 pikes were not reached. Major evolutions observed in LNG trading and LNG shipping come with a higher complexity for market analysts and forecasters. Such a complexity calls for a modelling platform such as the one proposed hereunder.

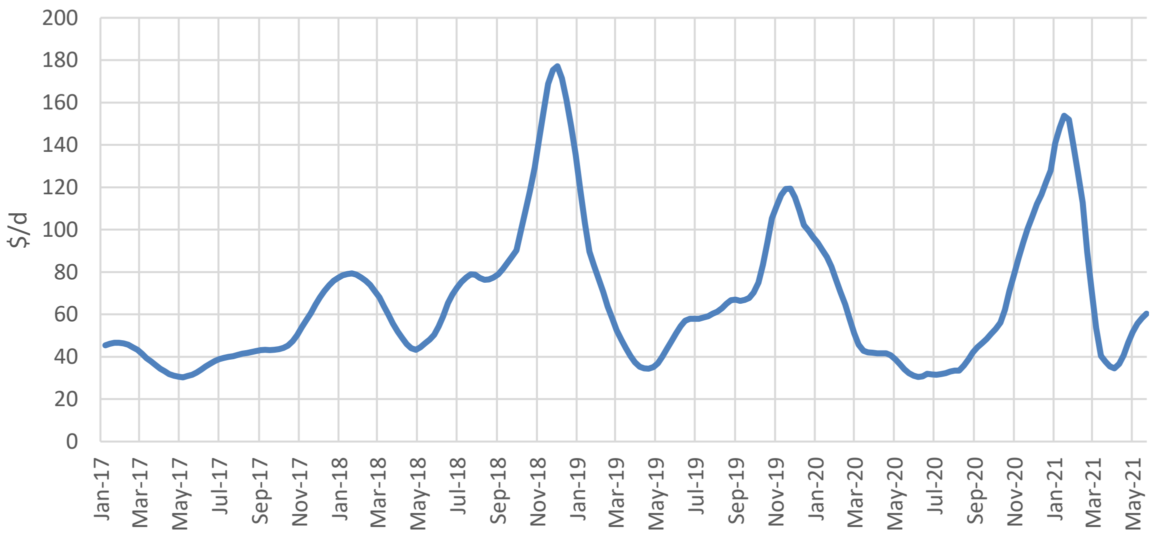

Figure 3: Historical estimated Spot Charter Rates 160 k cm

2. The trading model in details

The models provides a LNG flow allocation on a monthly basis based on a thorough description of physical and economic constraints.

2.1. LNG production

The monthly available LNG production capacity (t/month) is assessed for each liquefaction train. These production capacities are affected by the production ramp-up (new built trains), their periods of maintenance or the depletion of their upstream reserves.

Most of LNG liquefaction trains are integrated projects where upstream assets have been developed and are fully dedicated to the given liquefaction trains. In this case, the available production capacities are mainly affected by maintenance periods or upstream depletion. Short term LNG market developments are assumed to have no impact on the production capacity and LNG liquefaction costs are assumed to be stranded in this case, or in other words, these costs are assumed to have no impact on the LNG flows allocation.

The situation is different for US liquefaction trains which have been developed on a different business structure. In these cases, LNG liquefaction trains are supplied by natural gas from the domestic market. In this case, the liquefaction short term production costs of these trains are assessed at the Henry Hub price plus a normative tolling fee ($/mmbtu).

2.2. LNG demand

The monthly LNG demand (t/month) is assessed for each gas balancing zone based on local domestic natural gas markets fundamentals: sectoral demand, storage, domestic production, pipe imports/exports. The monthly available LNG regasification capacity is assessed for each regasification train based on their ramp up (new built trains) and maintenance periods. As regasification capacities booking mainly rely on multi-year slots, short term regasification capacities are considered as stranded in the model.

2.3. LNG shipping routes

LNG shipping routes are assessed on a port to port basis. For each route, the shipping costs ($/mmbtu) is assessed based on the route distance (nm), the vessel speed (knot), and the use of a normative LNG tanker long term breakeven cost ($/d). In this way, the longer the shipping route, the more expensive the associated shipping cost. Shipping costs are also affected by the transit through Suez and Panama canals, when needed.

Finally, the model also includes the boil-off gas which is the share of LNG which evaporates during the voyage and which is definitively lost. The cost of boil-off gas is priced at the short term LNG liquefaction cost which is stranded for non-US liquefaction trains. The boil-off gas also has an impact on the flow allocation as the longer the shipping route, the higher the volume of gas definitively lost during the voyage.

2.4. LNG contracts

LNG long term contracts with destination clauses are modeled to force LNG flows from the given LNG liquefaction train, plant our exporting country to the LNG regasification trains, plant or importing country.

2.5. Problem and resolution

The model is a least cost minimization model which provides a linear LNG flows allocation where the monthly LNG supply meets the LNG monthly demand. The models takes into account a series of physical and economic constraints:

Main physical constraints:

- Sum of physical LNG available production capacities for exporting balancing zones.
- Sum of physical LNG available liquefaction capacities for importing balancing zones.
- Impact of Boil-off gas for LNG shipping.
- LNG contracts with destination clauses.

Main economic constraints:

- LNG liquefaction lifting cost for US LNG production.
- Shipping cost as a function of the port to port distances, channels and boil-off.

2.6. Results

The model has been back tested on a 96-month periods from January 2012 to December 2019. The flows profile provided by the model shows great similitudes with historical flows.

We present hereunder the comparison of monthly flows on a 36-month period from January 2017 to December 2019 provided by our model against actual flows for 4 main trading LNG regions: the Middle East and Oceania LNG exports by importing regions, and the Europe and Asia LNG imports by exporting regions. These flows exclude reloading vessels.

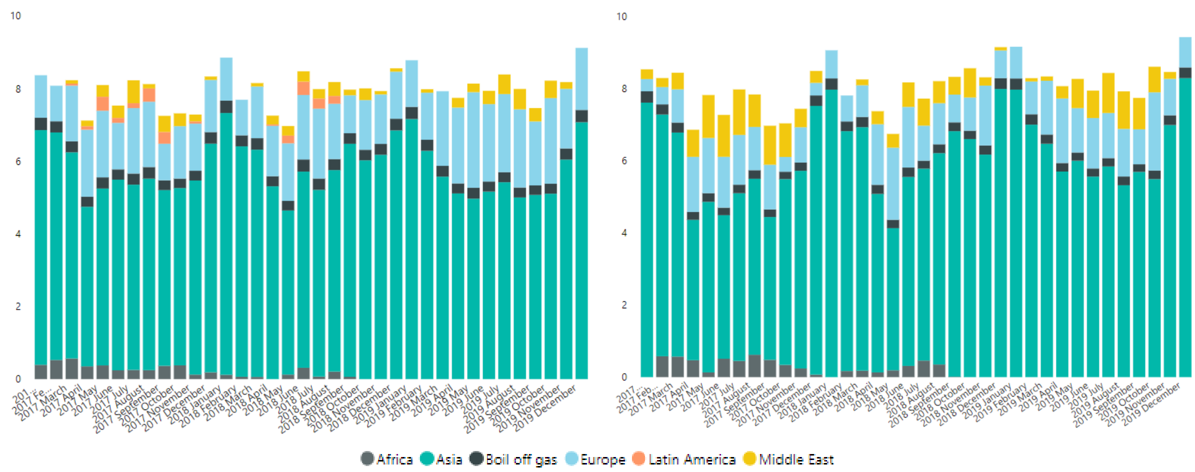

Figure 4: Monthly Middle East exports by importing region excl. reloading flows (Mt) left: actual flows, right: model's results

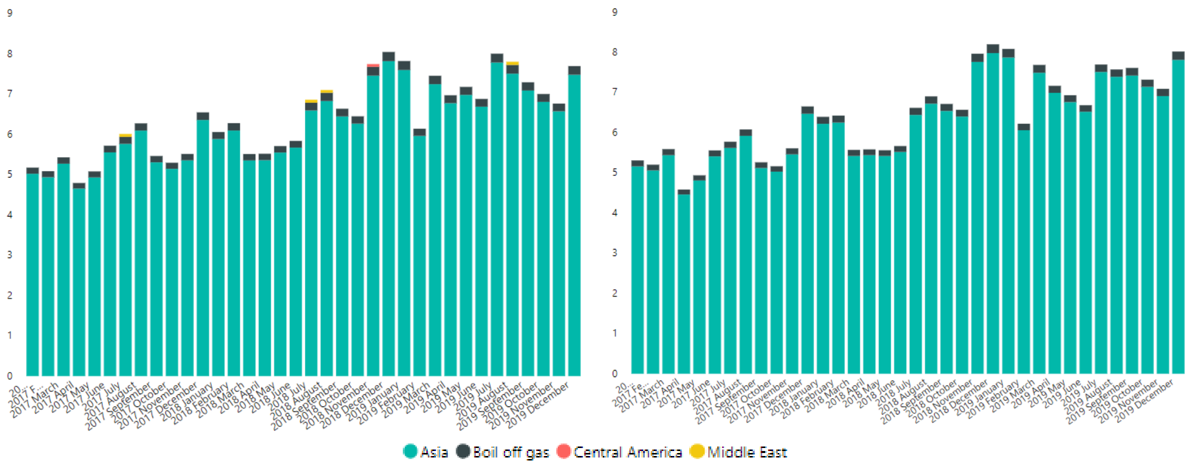

Figure 5: Monthly Oceania exports by importing region excl. reloading flows (Mt)
left: actual flows, right: model's results

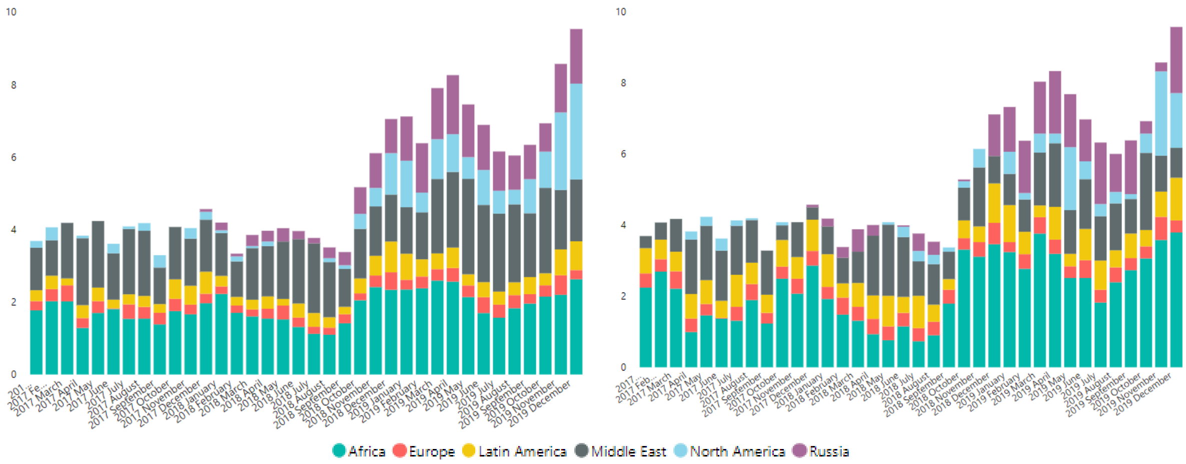

Figure 6: Monthly Europe imports by exporting region excl. reloading flows (Mt)
left: actual flows, right: model's results

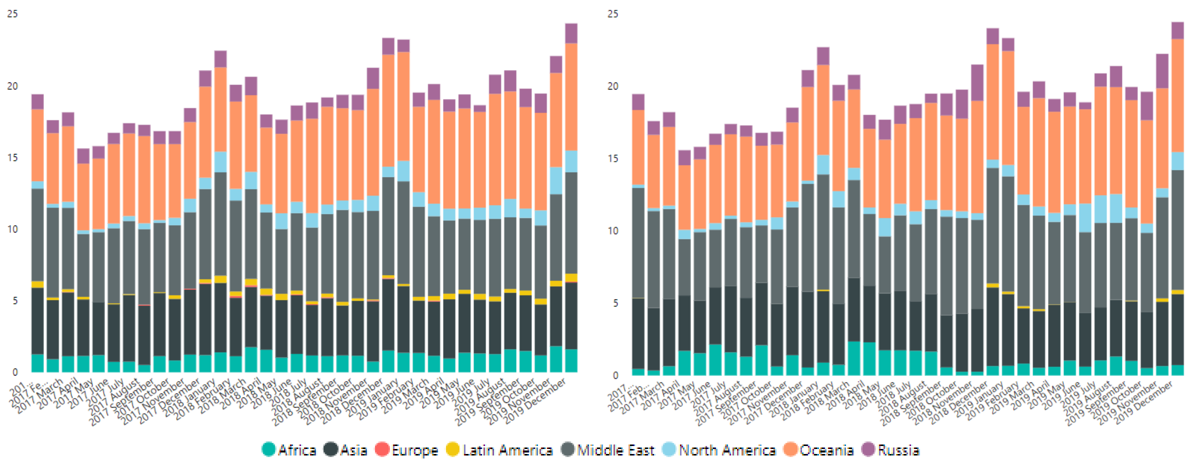

Figure 7: Monthly Asia imports by exporting region excl. reloading flows (Mt)
left: actual flows, right: model's results

At this point, the model provides valuable fundamental views on the LNG trading market of which (i) the destination of LNG exports for each liquefaction train and therefore the pricing of these exports (ii) the supply of each importing region and therefore their market price structure. However, several reasons may be sources of the discrepancies observed between the two flows allocation profiles.

From one hand, LNG portfolios are currently not included in our model. From the other hand, our model provides the market least cost minimized solution which is over-optimized in comparison with the actual market. We expect the growing commoditization of the LNG and LNG shipping markets to lead the actual market toward a more optimized market in coming years.

3. Developing the LNG shipping market model on the top of the LNG trading model

3.1. Shipping demand

In a similar way to other transport industries, the global LNG laden shipping demand is assessed in bcm.miles where:

- The LNG volume to ship is assessed in billion cubic meters of natural gas (bcm).
- The distance on which this LNG volume has to be shipped is assessed in nautic mile (nm).

By construction, our model provides a monthly view on this laden shipping demand.

On the top of the laden LNG shipping demand, we consider the global LNG shipping demand also includes ballast voyages (or vessels repositioning). In a first estimation, we consider the round trips for each vessel, which means that the distance of each ballast leg is equal to the previous laden leg.

3.2. Shipping supply

The shipping monthly supply is estimated as the monthly shipping capacity of the global LNG carriers trading fleet assessed in bcm.miles after a conversion of metric tons of LNG (Mt) to billion cubic meters (bcm) of natural gas.

For this, we first monitor the monthly LNG carriers trading fleet, which means the list of LNG carriers which are available for shipping LNG on a monthly basis. This monitoring implies a continuous view on LNG carriers removals and the global order book but also LNG carriers under repair status or LNG carriers under sanctions.

Then, this trading fleet is converted into a global shipping capacity in bcm.miles thanks to their standard estimated cargo size and speed:

$$\begin{aligned} &shipping\_capacity\_month\_m_{(bcm.miles)} \\ &= average\_cargo\_size_{(bcm)} * vessel_{speed_{(nm)}} * 24 * days\_in\_month\_m_{(\#days)} \end{aligned}$$

3.3. Market balance and spot charter rate

We then assess the global LNG fleet operating rate defined as the ratio between the shipping demand and the shipping supply as:

$$global\_fleet\_operating\_rate\_month\_m_{(\%)} = \frac{shipping\_demand\_month\_m_{(bcm.miles)}}{shipping\_capacity\_month\_m_{(bcm.miles)}}$$

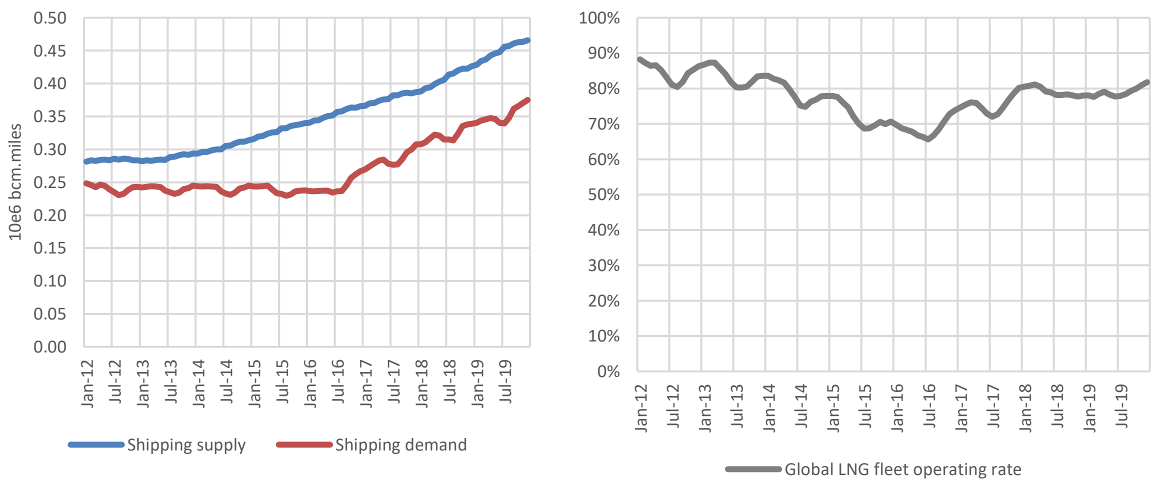

**Figure 8: left: monthly shipping demand and supply,
right: global LNG fleet monthly operating rate**

We then compare this global LNG fleet monthly operating rate to the LNG carriers spot charter rate for a 160.000 cm vessel (propulsion: Dual Fuel Diesel Electric, DFDE).

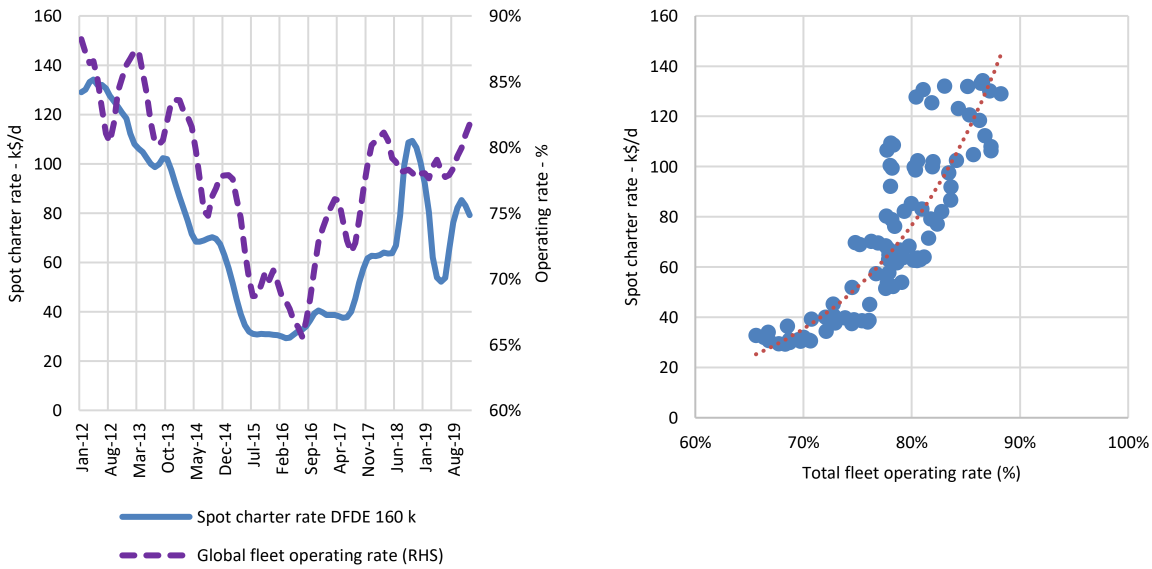

**Figure 9: left: monthly spot charter rates and global LNG fleet monthly operating rate,
right: spot charter rates and global LNG fleet operating rate correlation**

Our global LNG fleet operating rate proves a reliable correlation with the spot charter rate through the following equation:

$$spot\_charter\_rate_{(k\$/d)} = 0.161 * \ e^{7.706 * global\_fleet\_operating\_rate_{\%}}$$

$$R^2 = 0.801$$

We conclude the global LNG fleet operating rate is a significant fundamental indicator for the LNG shipping market and could be improved with further developments of which:

- Modelling of portfolios in the LNG trading model.
- Modelling of ballast travels in the shipping model.
- Modelling the evolving vessel speed according to market conditions.
- Differentiation of charter rates by propulsion technology and loading basin (East of Suez or Atlantic Basin).

Conclusion

The model provides insights into the LNG market and its associated shipping market and can support decision makers assessing associated risks and opportunities. Further developments are foreseen such as the modelling of the repositioning of ballast LNG carriers or the integration of the whole natural gas market with the aim to enhance the reliability of the market views.