What can be learned from the free destination option in the LNG *imbroglio*?

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LNG markets at a glance

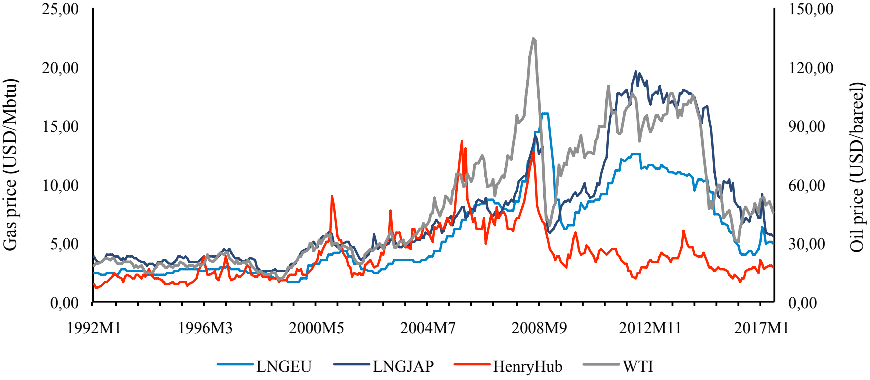


Figure: Natural gas import prices from the three main consuming regions and WTI crude oil price

Motivations

LNG markets are getting more flexible...

- Increase of spot and short-term LNG trade, less binding long-term contracts with decreased duration, relaxed inflexible clauses (e.g., take or pay obligations) and a change in the pricing terms toward hub-indexation (Ruester, 2009; Hartley, 2003)
- Volumes made available by US projects are sold Free on Board (FOB), ensuring 100% destination flexibility

...**BUT**

- This paradigm shift remains progressive: a transition period with new contracts still including destination clauses, oil indexation pricing formulas is expected in the medium-term horizon, especially in Asia
- The outlook of LNG is increasingly complex (Corbeau et al., 2016)

Motivations

Flexibility will be contractual:

- ✗ Uncontracted LNG supplies: limited volumes are expected to come on stream (IEA, 2016)
- ✗ Portfolio players: ambigous impact in terms of flexibility (Rogers, 2017)
- ✓ **Diverted LNG supplies : only option effectively providing flexibility**

Addressed questions:

- In this transition period, how valuable is the free destination option in long-term LNG supplies?
- How is the diverting option affected by the increasing uncertainties in the medium-term horizon of LNG markets?

This paper

- Use and extend Rodriguez's (2008) model to evaluate the opportunity of flexible routing by LNG cargoes for a single supplier by taking into account uncertainty in the medium term dynamics of the gas markets
- First we represent the trajectory of future LNG prices based on an estimated threshold vector autoregression model (TVAR) in which the system switches back and forth between high and low regime of oil price uncertainty
- Then we generate Monte Carlo simulations for the future LNG price series and the subsequent shipping decisions to get the distribution of values for the diversion option.
- Main result: the value of the option is still a very important part of the LNG value and is substantially higher in high regime of oil price uncertainty

Literature

- LT contracts in specialized markets are needed to minimize transaction costs, avoid the hold-up risk (Williamson, 1979). Reputation and repeat transactions are not enough to prevent strategic behavior without formal commitments (Masten, 1993)
- Neuhoff and Von Hirschhausen (2005) studied the role of LT contracts under the liberalization point of view and Von Hirschhausen and Neumann (2008) focused on factors affecting contracts duration
- Destination clauses hampers NG trade and gas-to-gas competition (Glachant and Hallack, 2009) and commercial reasons underpinning destinations clauses are not clear (JFTC, 2017)
- Shi and Variam's (2016) results suggest that the removal of destination clause in East-Asian long term contracts should be the priority over indexation issues

Benchmark Model: Rodrìguez (2008)

General approach of the real option model

- Compare a base case where the supplier is commited to send LNG to a unique destination and a free destination case where LNG can be flowed to one or two alternatives markets
- Extra-transportation costs reflect, among others, fuel oil cost, carrier day rate, ship size, trip length

Supplier location

1. Australia
2. US
3. Qatar
4. Nigeria
5. Algeria

Benchmark Model: Rodrìguez (2008)

- The unit value of destination flexibility option for a unit production capacity in a given month m given by:

$$v(m) = max(P_{Alternative}(m) - P_{Initial}(m) - \triangle T(m); 0) \qquad (1)$$

with $P_{Alternative}$: the average price of LNG in a future month m in the three possible alternative markets and $P_Initial(m)$ the average price of LNG in the initial market in a future month m.

- $v(m)$ has to be compared with the value of LNG supply without destination flexibility:

$$v(\bar{m}) = max(P_{initial}(m) - T_{initial}(m); 0) \qquad (2)$$

Benchmark Model: Rodrìguez (2008)

- The results of each scenario are presented in terms of monthly average unit of $v(m)$ for a supply period of 3 years. The value V of destination flexibility as the discounted sum of $v(m)$ over the supply period:

$$V = \frac{\sum_{m=1}^{T} v(m).\delta^m}{\sum_{m=1}^{T} \delta^m} \tag{3}$$

with δ the risk free discount factor. V is compared to the average unit value for an inflexible project:

$$\bar{V} = \frac{\sum_{m=1}^{T} v(\bar{m}).\delta^m}{\sum_{m=1}^{T} \delta^m} \tag{4}$$

Model for future LNG prices

Represent the trajectory of future LNG prices in the three main consuming regions:

1. Exploit their inter-relationships by moving beyond of the cointegrating framework that leads to the absence of a cointegrating relationship (e.g., Siliverstovs et al., 2005)
2. Consider the presence of structural breaks (e.g., the Fukushima disaster) and the nonlinearities that govern these relations which are related to the presence of transaction costs, market power (Ritz, 2014), asymmetry of the economic cycle and inherent rigidity in the market
3. Recognize the uncertainties that may affect the future dynamics of the LNG markets:
   - Asian demand? Transition to market-related pricing?
   - Balancing role of Europe?
   - Where oil price will stabilise?

Threshold Vectorial Autoegressive Model (Balke, 2000)

- The idea of approximating a general nonlinear autoregressive structure by a threshold autoregression with a small number of regimes is due to Tong (1990).
- Capture non linearities such as regime switching and asymetries
- Threshold models work by splitting the times series endogenously into different regimes
- Within each regime, the time series is assumed to be described by a linear model

TVAR Model: choice of the transition variable

Oil price uncertainty as a nonlinear propagator of shocks:

- persisting oil indexation in long-term contracts over the medium-term horizon: oil indexation in Asia is expected to slightly decrease, moving from 78% in 2016 to 69% in 2022 (Rogers, 2017)
- the impact of oil price uncertainty on global economic activity (Bernanke, 1983; Elder and Serletis, 2010)
- high degree of price competition between the two commodities (Brown and Yücel, 2008; Villar and Joutz, 2006)
- the strong theoritical and empirical support for a nonlinear price transmission (Grégoire et al., 2009; Brigida, 2014)

Uncertainty regimes

High uncertain scenario

- $\uparrow$ uncertainty about the use of oil-indexation in LT contracts with a relatively fast transition toward a more flexible reconfiguration
- $\uparrow$ uncertainty about the future of global gas demand (especially in Asia with a fast restart of nuclear power)
- $\uparrow$ uncertainty about the macroeconomic outlook

Low uncertain scenario

- Persisting oil-indexation in the pricing terms of LT contracts with a time-consuming transition
- A situation that does not really deviate from the current market configuration

TVAR Model

TVAR model can be specified as follows:

$$Y_t = A^1 Y_t + \ B^1(L) Y_{t-1} + (A^2 Y_t + B^2(L) Y_{t-1}) I[s_{t-d>\gamma}] + U_t \qquad (5)$$

with:

- Y_t: a vector containing the endogenous stationary variables (JAP LNG, EU LNG ans US HH and oil price volatility.
- $B^1(L)$ and $B^2(L)$ are lag polynomial matrices and U_t is the vector of disturbances.
- s_{t-d} is the threshold variable which determines the prevailing regime of the system.
- I is an indicator function that takes the value one when the transition variable exceeds the threshold value γ and 0 otherwise.

Proxy of oil price uncertainty

Monthly volatility for the international crude oil price

(Daily log returns of Spot WTI)

- Oil price volatility is a significant predictor of natural gas returns (Pindyck, 2004)
- Does not require any parametric model with strong hypothesis and provides unbiased estimators of the underlying latent volatility (Fleming et al., 2001)
- Volatility persistence is less important in the oil market than in the gas market meaning that the unconditional variance would yied a good forecast of the future volatility (Ewing et al., 2012)

Empirical Analysis

1. Sample period: 1992M01-2017M06.
2. Monthly data obtained from the IMF Primary Commodity prices
   i) US LNG: Henry Hub natural gas spot price
   ii) EU LNG: Russian natural gas border price in Germany
   iii) JAP LNG: LNG import price from Indonesia
   iv) Weekly spot prices of West Texas Intermediate (WTI)
3. Delay *d* of the transition variable is set to be 3
4. The number of lags in the VAR is set to be 3 in compliance with AIC and HQ information criterions

Table: Summary statistics

	Henry Hub	LNG EU	LNG JAP	WTI
Mean	3.971	5.794	7.639	8.944
Median	3.323	4.155	5.825	7.071
Maximum	13.634	16.020	19.570	25.634
Minimum	1.180	1.670	2.570	2.082
Std. Dev.	2.251	3.644	4.786	5.641
Skewness	1.507	0.787	1.108	0.668
Kurtosis	5.670	2.470	3.002	2.191
Jarque-Bera	206.760	35.138	62.662	31.086
Probability	0.000	0.000	0.000	0.000
N	306	306	306	306

Note: The descriptive statistics of the prices in level are reported. To check the stationarity properties of the series, we used an Augmented Dickey-Fuller (1979) and a Philipps-Perron (1988) tests. The series are all integrated of order 1 according to all test results. All variables have been transformed into the first-logarithmic difference form.

Linear VAR against TVAR

- An important question is whether the estimated TVAR model is statistically significant relative to a linear VAR
- As the threshold is unknown and need to be estimated, the TVAR is estimated by least squares for all possible threshold values
- For each possible value of the threshold, we test the hypothesis that the coefficients of the the model are equal accross regimes by calculating Wald statistics
- Three tests are computed: sup-Wald, avg-Wald and exp-Wald which respectively represent the maximum, average and function of the sum of exponential Wald statistics over all possible threshold values (Hansen, 1996)
- The estimated threshold values are those that maximize the logarithmic determinant of residual variance-covariance matrix

- Test of Linear VAR against a threshold alternative

Table: Test for threshold VAR

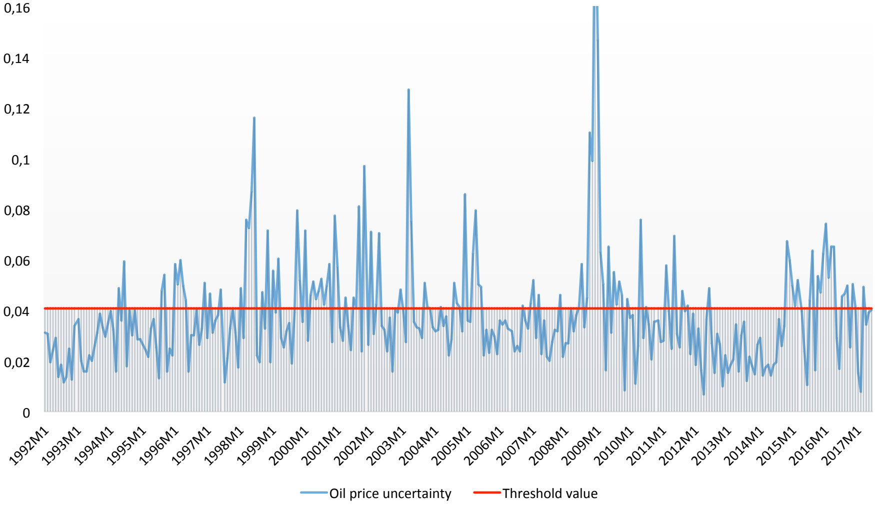
System includes LNG prices in JAP, EU, US HH and oil price volatility

	Wald Statistics		
Estimated Threshold Value	Sup-	Avg-	Exp-
$\gamma = 0{,}04055$	747.7951	705.6225	705.1870
	(0.000)	(0.000)	(0.000)

Note : The response of LNG prices to changes in uncertainty context is supposed to occur with a delay *d* of 3 months and the threshold variable is represented as a three-period moving average.

P-values based on Hansen's (1996) procedure method of inference with 500 replications are in parentheses.

Empirical analysis



Evolution of oil price uncertainty and the estimated threshold value

Arbitrage scenarios

LNG prices forecast by 2020

- Price differentials between the US and Europe/Asia will still be very significant in the coming years
- Downward trend of LNG prices in Japan in high regime of uncertainty ($\downarrow$ oil indexation + fast nuclear restart)
- European prices are higher in the high regime
- End of the Asian premium with a tightening of price differentials between Europe and Asia especially in the low regime (persisting reliance to oil-indexation)

Shipping considerations

Table: Freight route costs in USD/MBtu

	Japan	South West Europe	North East US
Middle East	0.62	0.74	0.92
Australia	0.35	1.04	0.9
Nigeria	1.07	0.37	0.3
Algeria	1.23	0.08	0.19
US Gulf Coast	1.13	0.47	-

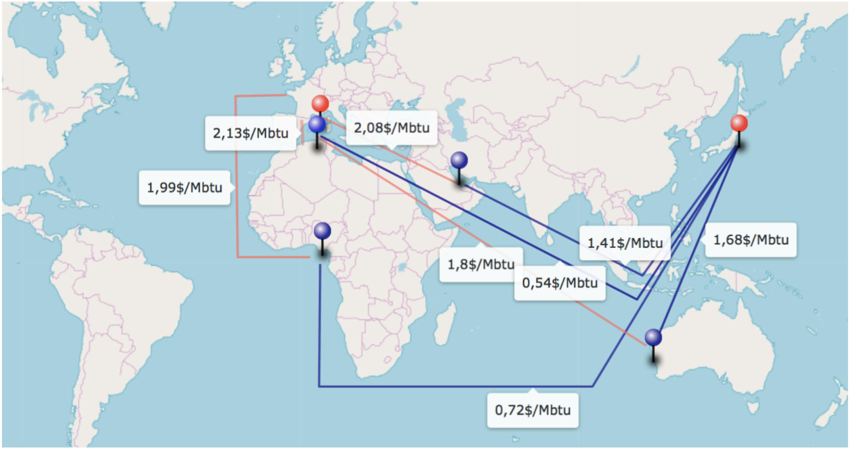
Source: Platts

Table: Shipping days

	Japan	South West Europe	North East US
Middle East	15	13	22
Australia	8	21	29
Nigeria	26	9	13
Algeria	24	1	9
US Gulf Coast	2	12	-

Source: Platts

Result 1: Significant arbitrage opportunities between US and EU/Japan



Expected value of the free destination option when suppliers are initially commited to serve US - HR

Result 2: Arbitrage opportunities between US and EU/JAP are found to be more profitable in the high regime

Supplier	Initial	Alternative(s)	Uncertainty Regime	Flexibility option	Gain
Algeria	US	Europe	Low Regime	1,39 $/mmbtu	130%
			High Regime	2,13 $/mmbtu	74%
Australia	US	Europe, Japan	Low Regime	1,76 $/mmbtu	248%
			High Regime	2,02 $/mmbtu	87%
Nigeria	US	Europe	Low Regime	1,35 $/mmbtu	134%
			High Regime	1,99 $/mmbtu	72%
Qatar	US	Japan, Europe	Low Regime	1,68 $/mmbtu	224%
			High Regime	2,13 $/mmbtu	93%

Expected value of the free option when suppliers are initially commited to serve US

Sensitivity analysis to extra-maritime costs

By increasing extra transportation costs to alternative markets from 10% to 50%, we find that

- for all suppliers involved in US-Japan and US-Europe arbitrages, the value of the free destination option turns out to be more sensitive to extra-transportation costs in HR
- when the arbitrage decision hinges on the dynamics of the Japanese and European markets the sensitivity to the additional maritime costs is not higher in the HR

Conclusions

- The exercise of the valued options gives an indication of the direction of future LNG flows by 2020:
  - **US LNG** would prominently go to Europe in both scenarios but is more likely to end up in Europe in a low uncertain scenario
  - **Australian and Middle Eastern LNG** are expected to be moved towards the Japanese market and the European alternative would be profitable only when a producer was initially committed to serve the US for both scenarios
  - **African LNG** will be found mainly in Europe with a higher probability of diverting Algerian LNG to Japan than Nigerian LNG given its lower sensitivity to extra maritime costs
- Need to optimize LNG flows and additional costs of diversion must be taken into account

What can be learned from the free destination option?

- From the industry standpoint: it's an important source of value for profit motive actors who are in position to arbitrage and the recent arrival of trading houses in this market would be prominent in terms of flexibility and market diversification; and the present work should help to understand how to value and manage these participants businesses
- From a security of supply standpoint: with relatively low physical flexibility from the LNG export infrastructure and high utilisation of liquefaction plants that tend to be base load, making possible for the contracting parties to shift the destination of LNG delivery would play a pivotal role in terms of the resiliency to unforeseen events

What can be learned from the free destination option?

Market integration debate

- The destination option highlights the benefits of greater future market spotification as even partners engaged in long-term contracts could profit from a participation in the spot market
- If it goes in tandem with a lower indexation of oil prices and market forces driving prices and movements of vessels, then in this precise case, one would expect a possible "convergence".
- Focusing on destination flexibility will thus be an effective way of giving some momentum to a quasi unescapable transition period especially for the asian markets. In this respect, our results are in perfect agreement with those of Shi and Variam (2016) who advocate a prioritisation of the destination issue in the contractual terms of LNG sales

Thank you!