Supporting document

This document provides further details on the way we have used the constructed data-driven time series model of the regional LNG prices to calculate the free destination real option.

Precisions are given in the following order:

I. Stationarity tests

II. Linearity tests

III. Computation of nonlinear impulse response functions

IV. Robustness checks

V. LNG prices forecasts and computation of the free destination option

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I. Stationarity tests

Perron (89) Unit root test with a breakpoint

		Break Date	Constant and Trend	Constant
US LNG	Level	2008M06	**-5.529**	-2.94
			[0.019**]	[0.718]
	Difference	1992M07	-17.356	**-17.372**
			< 0.01*	< 0.01*
Japan LNG	Level	2014M12	**-3.564**	-2.644
			[0.653]	[0.853]
	Difference	1992M05	-14.288	**-14.288**
			< 0.01*	< 0.01*
EU LNG	Level	2014M12	**-3.475**	-2.803
			[0.707]	[0.785]
	Difference	1992M05	-13.81	**-13.83**
			< 0.01*	< 0.01*

Note: Critical values are based on Vogelsang, 1993. Associated P-values are in brackets.
 * & ** denote the rejection of the null hypothesis at 1% and 5% respectively.
Break selection is based on Dickey-Fuller t-statistic minimization. We have considered innovationnal outliers break type.

		Augmented Dickey-Fuller Test (ADF)			Philips-Perron Test (PP)		
		Constant & Trend	Constant	None	Constant & Trend	Constant	None
US LNG	Level	-2.900168	**-2.922152**	-1.322669	-3.004255	**-3.00722**	-1.21081
		[0.1639]	[0.044**]	[0.172]	[0.1327]	[0.0353**]	[0.207]
	Difference	-17.41346	-17.42632	**-17.45402**	-17.67014	-17.60274	**-17.63393**
		[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]
Japan LNG	Level	-1.182313	-1.424223	**-0.620542**	-1.315205	-1.450283	**-0.656436**
		[0.9116]	[0.5705]	[0.448]	[0.8822]	[0.5576]	[0.4323]
	Difference	-14.35863	-14.33829	**-14.36057**	-14.35863	-14.31405	**-14.33652**
		[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]
Europe LNG	Level	-3.05455	-2.046559	**-0.886042**	-1.949002	-1.773602	**-0.75808**
		[0.1194]	[0.2669]	[0.3316]	[0.6261]	[0.3933]	[0.3873]
	Difference	-6.349587	-6.337779	**-6.344259**	-14.68076	-14.68079	**-14.69798**
		[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]	[0.0000*]

Note: The Shwarz information criterion is used for optimal lag selection in ADF test. The truncation lags for PP are decided by Newey-West default.
Critical values are based on MacKinnon (1996). Associated P-values are in brackets. *,** denote the rejection of the null hypothesis at 1% and 5% respectively.

II. Linearity tests

A – We relied on a Multivariate extension of the linearity against threshold test from Hansen (1999) with bootstrap distribution. This test is the multivariate extension proposed by Lo and Zivot of the linearity test of Hansen (1999). As in univariate case, estimation of the first threshold parameter is made with Constrained Least Squares; for the second threshold, a conditional search with one iteration is made. Instead of a F-test comparing the SSR for the univariate case, a Likelihood Ratio (LR) test comparing the covariance matrix of each model is computed.

We used the R software environment to run this test. Please run the LRtest.R program to get the test's results (tdDyn package need to be installed).

References:

Hansen (1999) Testing for linearity, Journal of Economic Surveys, Volume 13, Number 5, December 1999, pp.551-576(26)

Lo and Zivot (2001) "Threshold Cointegration and Nonlinear Adjustment to the Law of One Price," Macroeconomic Dynamics, Cambridge University Press, vol. 5(4), pages 533-76, September.

B - We have also computed the sup-Wald, Avg-wald and Exp-wald statistics to see whether the estimated TVAR model is statistically significant relative to a linear VAR via the WinRATS Econometrics software using the code provided by Nathan Balke which we adapted to our analysis (Please run tvar_estimation.PRG program to get the test's results).

As the threshold value is unknown and need to be estimated, the threshold model is estimated by least square for all possible threshold values. For each possible value of the threshold, we test the hypothesis that the coefficients of the model are equal across regimes by calculating Wald statistics. More specifically, 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 (See Hansen, 1996 for the simulation method used here to conduct inference). The estimated threshold values are those that maximize the logarithmic determinant of residual variance-covariance matrix.

Same conclusions are drawn from the two tests.

Note: Results of this test does not appear on the core document.

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III. Computation of nonlinear impulse response functions

We estimated the TVAR with WinRats Econometrics software using the code provided by Nathan Balke which we adapted to our analysis.

Please go to the tvar_irf.PRG program to run the code we have used to compute the nonlinear impulse response functions. The data we have used are in the data.xls file.

The method for computing generalized impulse response functions follows Balke's (2000).

The employed algorithm is the following:

1. Pick a history $\Omega r\ t{-}1$ of all the lagged endogenous variables of the model at a particular date.

2. Pick a sequence of shocks from the covariance matrix by bootstrapping the estimated residuals of the TVAR model. The residuals are assumed to be jointly distributed.

3. Using this sequence of shocks, we produce forecasts conditional on initial conditions $\Omega r\ t{-}1$ by simulation.

4. We repeat step 3 by adding a new shock at time 0 equal to +/- 1 or 2 SD.

5. We repeat steps 2 to 4 are B times (B=500).

6. We repeat steps 1 to 5 R times and compute the average impulse response function as the average difference between the forecast from step 3 and 4.

Note: The ordering of the variables in the VAR are supported by the Granger causality test that we run on EViews.

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IV. Robustness checks

We have tested the robustness of the model to different specifications of the threshold VAR model and the variables. More specifically, we have tested its robustness to variations in the number of lags in the TVAR system (the model is robust to reasonable alternative lags from 2 to 8), to different delays d of the transition variable (from 1 to 5) and different orders of the moving average process (from 1 to 8). Besides, we have also tested the robustness of the model specification to a threshold variable measured by using daily WTI spot prices to calculate the sample standard deviations of adjusted log price changes.

Moreover, we have considered another proxy of uncertainty to test the robustness of the model to another transition variable: we have retained the Chicago Board of Exchange VXO stock market volatility measure (the associate time series data is available on the data.xls file; the LRtest.R program could be used to get the linearity test results associated with the CBOE VXO threshold). The CBOE VXO index is more associated to a financial market uncertainty and shows the market's expectations of 30-day volatility and hence is primarily forward-looking (unlike the backward-looking volatility of the price of oil as we have retained). This alternative threshold variable turns out to make little difference in terms of our testing of a threshold specification and also in terms of conclusions of the impulse response functions (results are available upon request).

Note: In the tvar_irf.PRG, diagnostic checks of the TVAR residuals in each regime have been performed. Overall, for both high and low regime of oil price uncertainty, we cannot reject the null hypothesis of absence of ARCH effects in the residuals. Moreover, we have applied the Ljung-Box test to the TVAR residuals and results suggest that there is no serial autocorrelation.

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V. LNG prices forecasts and computation of the free destination option

As the multivariate forecast errors are asymptotically normally distributed with covariance matrix, the forecasts of Y_{t+h} (vector of endogenous variables containing LNG prices in US, Japan, Europe and the uncertainty measure) are simulated by generating multivariate normal random variables with mean zero and covariance matrix from the residuals of the regime-dependent estimated TVAR. More specifically, we use Multivariate Monte-Carlo Simulations to generate the future LNG prices paths for each regime of uncertainty upon which the computation of the value of the free destination option is based. This choice is supported by the results of the Andersen-Darling normality test applied to the residuals distribution in each regime (Please open the tvar_irf.PRG and run the normality test in diagnostic check part to get the results).

Using the Monte Carlo method, 10,000 potential price series are generated for each uncertainty regime. Each individual simulation of future prices for the Japan, US and Europe generates a series of price spreads. When the price spread is enough to cover the additional cost of transportation, cargoes are diverted from their initial destinations.

Note: we used a spreadsheet modeling program, Microsoft Excel, and the Monte Carlo Simulation Excel

Add-in program to conduct Monte Carlo simulations of future LNG prices and compute the associated regime-specific value of destination flexibility for each producer either based in Australia, US, Qatar, Nigeria and Algeria.