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Developments in the LNG market

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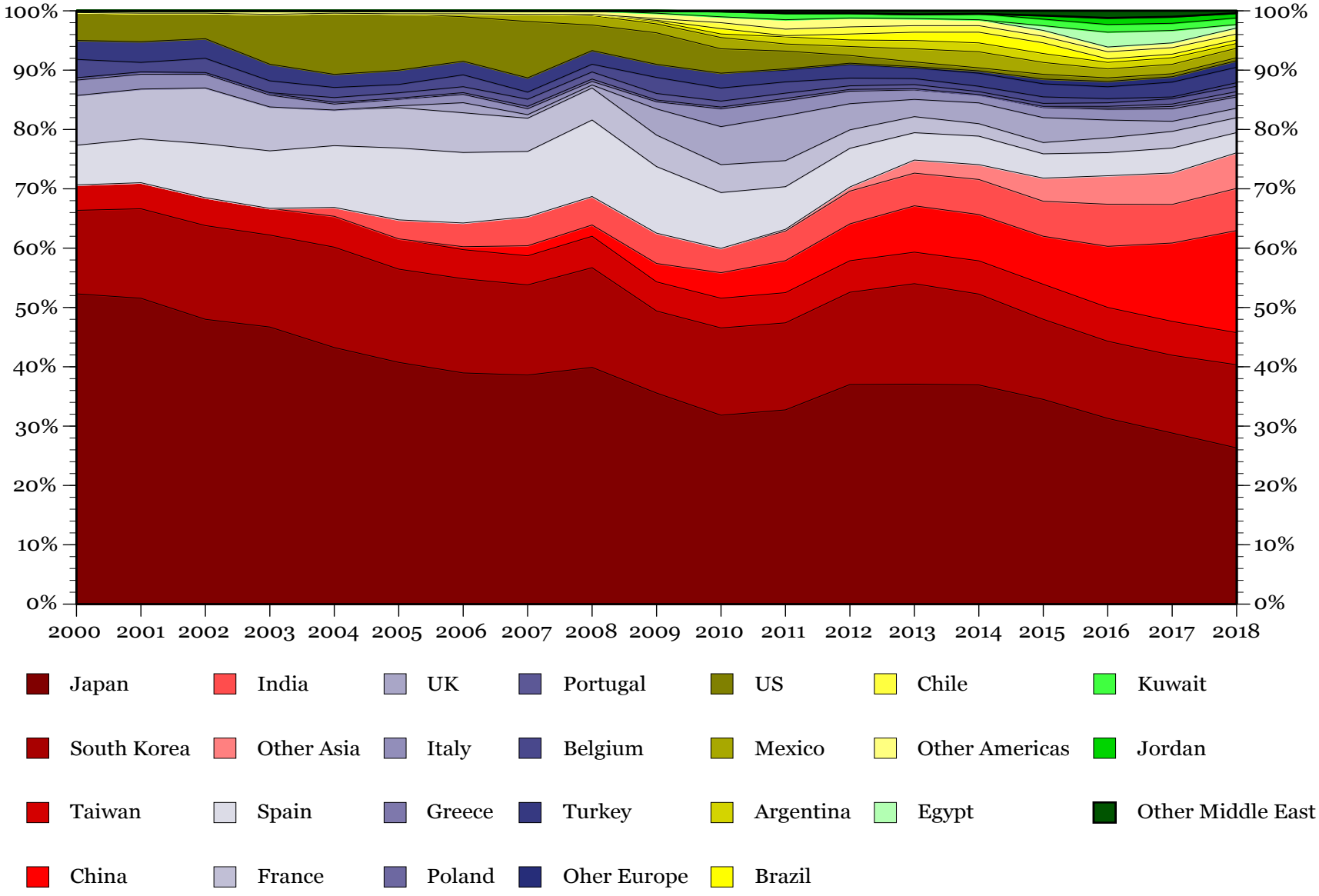
Recent LNG market developments

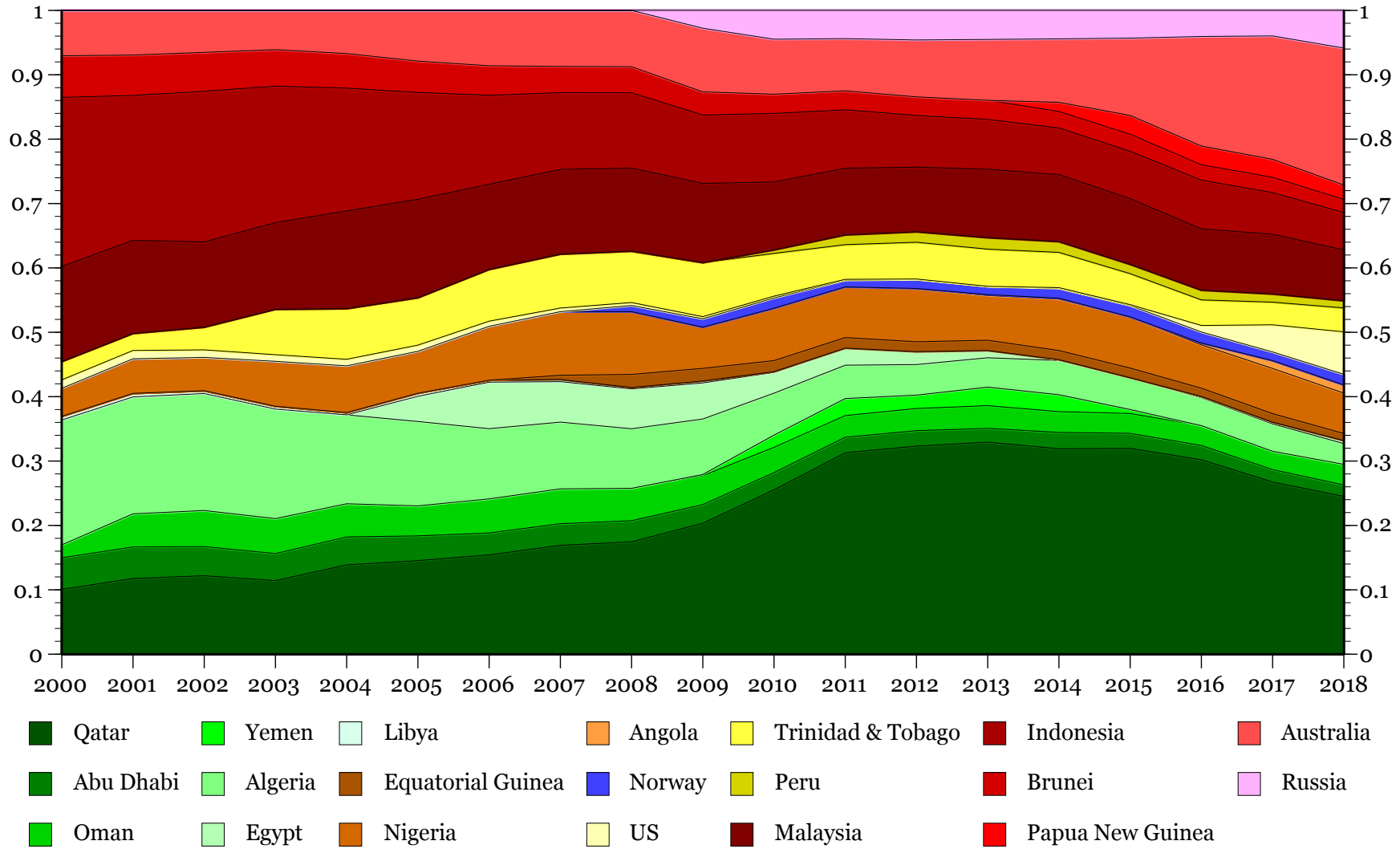
- LNG trade growth > natural gas trade growth ≅ TPE growth
- LNG market is becoming more global:
  - Many more sellers and especially buyers
  - Traders becoming more dispersed geographically
- Moving away from long-term, bilateral trading contracts toward spot and short-term, and more flexible contracts
- Key question: What does this say about the role of natural gas in the future?

Regional composition of LNG imports



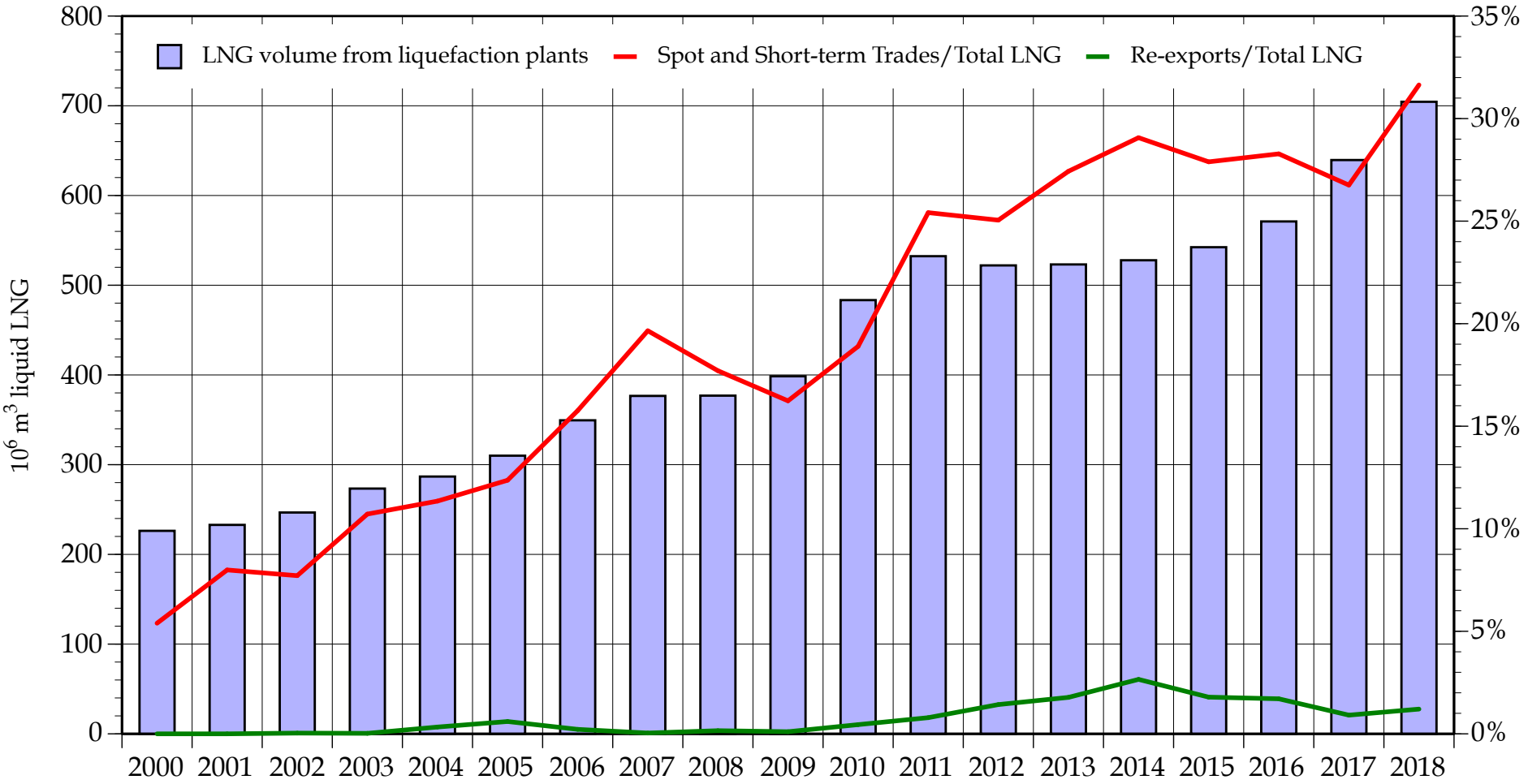
Source: GIIGNL

Regional composition of LNG exports



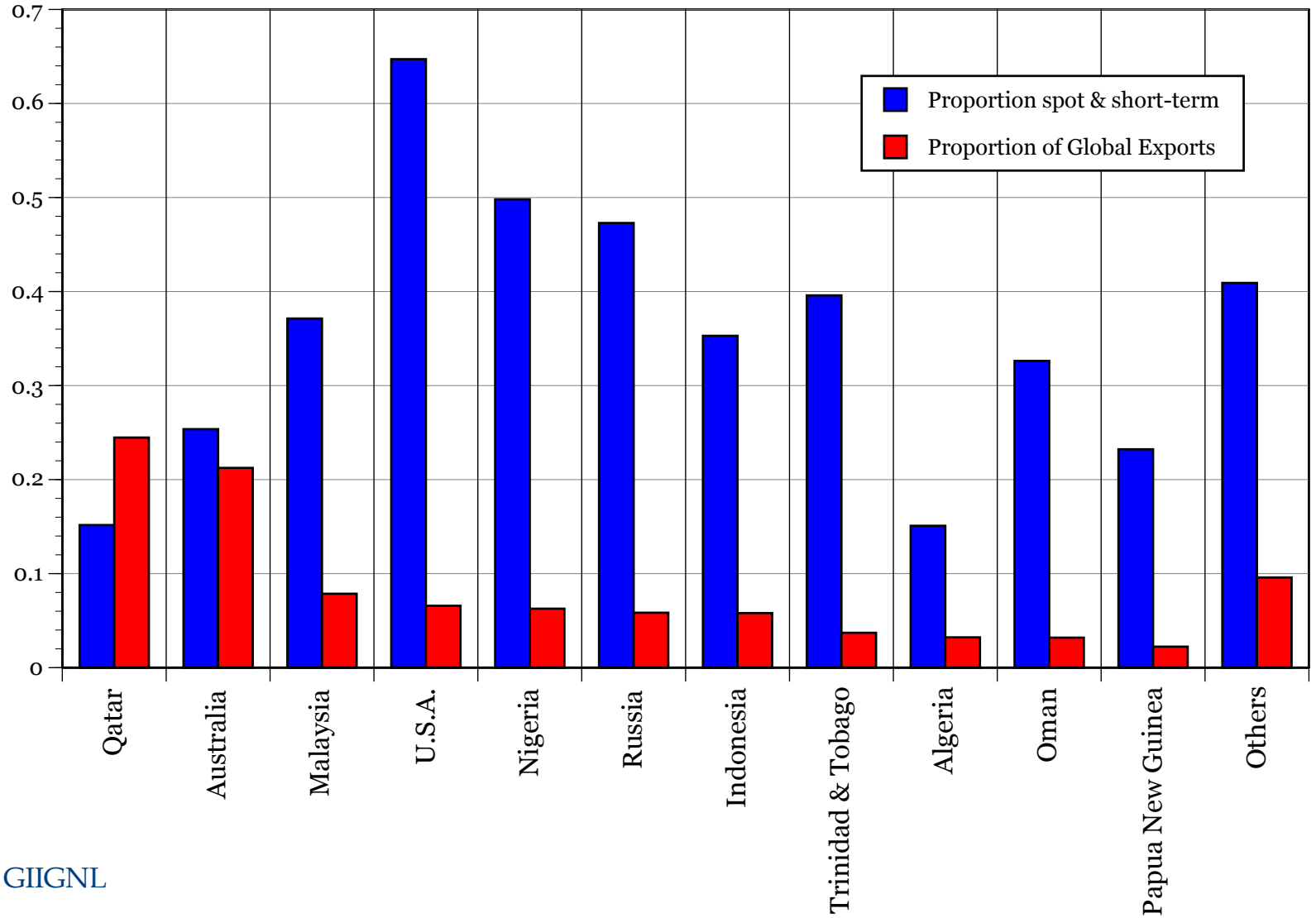
Source: GIIGNL

Overall LNG trade: Long and short term



Source: GIIGNL

Spot & short-term exports, 2018



Source: GIIGNL

US as a major exporter

- US will become a major supplier to Asia, which still takes more than 75% of global LNG
  - US advantages:
    - Lower capital costs of initial US projects
    - Reduced need for debt finance and thus for long-term contracts
    - More exports likely to be short-term and more available for arbitrage
    - Atlantic and Mediterranean markets can be accessed to south and east, South Asia via Suez Canal and East Asia via Panama Canal
    - Import/export access to deep North American gas market with substantial storage and extensive derivatives trading
  - US disadvantages:
    - Relatively high transportation costs
    - Higher average, and especially more variable, net (after liquid sales) feed gas cost than projects based on otherwise "stranded gas"
- US LNG plants are essentially real options on export netback minus HH

US LNG Exports February 2016–Nov 2019

Country of destination	Quantity (MT)	% of total US LNG exports
South Korea	12.91	17.3
Mexico	10.14	13.6
Japan	7.76	10.4
China	4.61	6.2
Spain	4.09	5.5
India	3.75	5.0
Chile	3.73	5.0
U.K.	3.03	4.1
France	2.52	3.4
Brazil	2.48	3.3
Jordan	2.44	3.3
Argentina	2.07	2.8
Turkey	1.81	2.4
Netherlands	1.73	2.3
Italy	1.73	2.3
Portugal	1.72	2.3
Kuwait	0.99	1.3
Taiwan	0.96	1.3
U.A.E.	0.85	1.1
Pakistan	0.82	1.1
Poland	0.78	1.1
Others (17 countries)	3.54	4.8
Total	**74.47**	

East/SE Asia 27.18

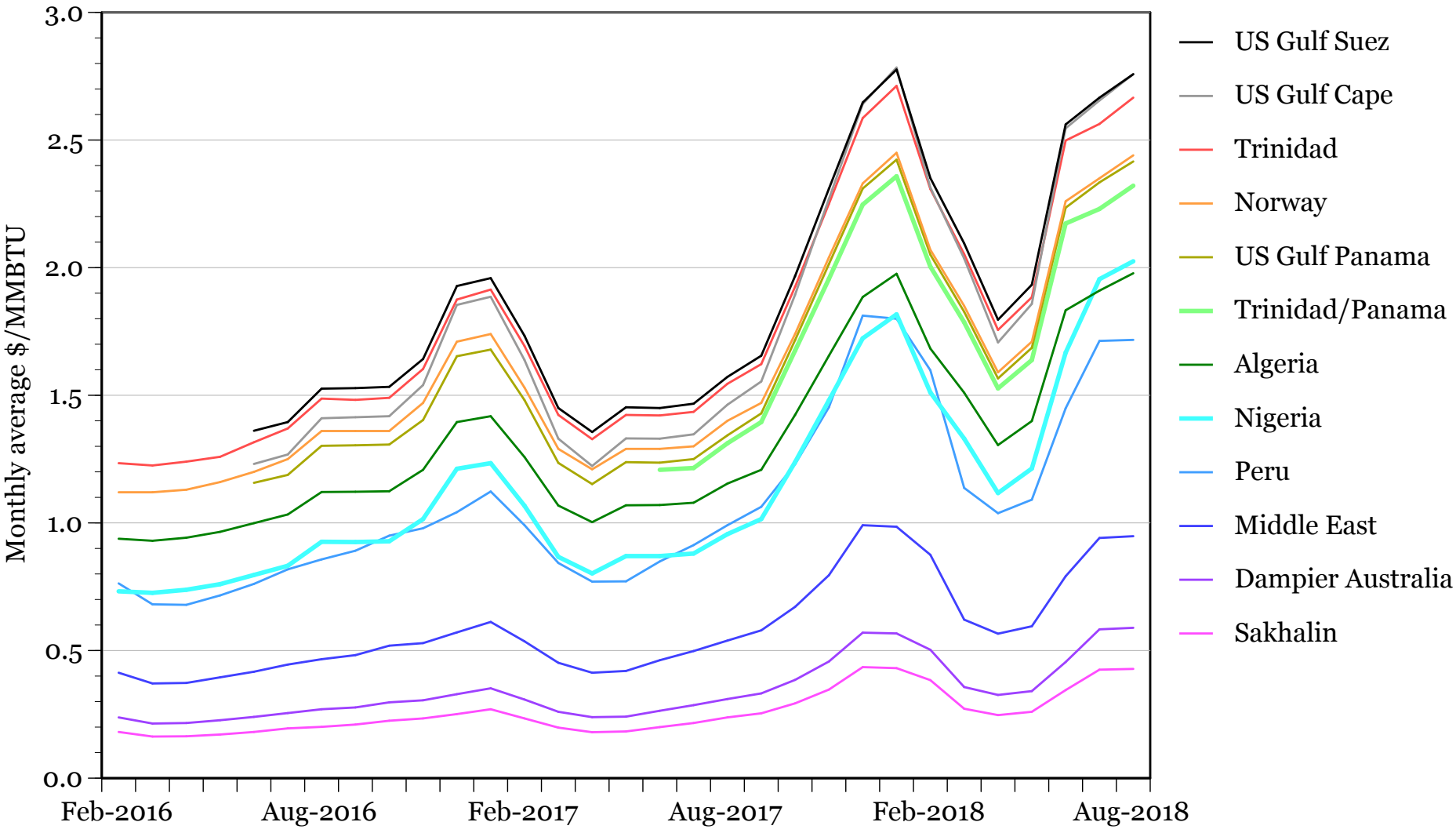
Americas 19.87

Europe 18.57

South/West Asia 8.86

Source: EIA

LNG freight rates to S. China or Taiwan



Source: Platts

Operational/In construction US LNG export terminals

Terminal status and location	Capacity bcf/d	As % 2018 LNG exports
Operational		
Sabine Pass, LA (trains 1-5)	3.45	8.3
Cove Point, MD	0.76	1.8
Corpus Christi, TX (trains 1-2)	1.32	3.2
Cameron, LA (train 1)	0.71	1.7
Freeport, TX (trains 1-2)	1.42	3.4
Sub-total operational	**7.66**	**18.5**
Under construction		
Cameron, LA (trains 2-3)	1.42	3.4
Freeport, TX (train 3)	0.71	1.7
Corpus Christi, TX (train 3)	0.66	1.6
Sabine Pass, LA (train 6)	0.69	1.7
Elba Island, GA	0.36	0.9
Golden Pass, TX	2.20	5.3
Calcasieu Pass, LA	1.70	4.1
Sub-total under construction	**7.74**	**18.7**

Source: EIA

US LNG export terminals approved but not under construction

Terminal and location	Capacity bcf/d	As % 2018 LNG exports
Lake Charles, LA (Southern Union)	2.2	5.3
Magnolia LNG, LA	1.2	2.9
Delfin FLNG	1.6	3.9
Driftwood LNG, LA	3.64	8.8
Port Arthur, TX	1.8	4.4
Freeport, TX (train 4)	0.7	1.7
Gulf LNG, MS	1.5	3.6
Plaquemines, LA	2.6	6.3
Sub-total approved, not under construction	**15.24**	**36.9**

Source: FERC

Other (international) projects to 2018-2025

Terminal and location	Start year	Capacity as % 2018 LNG exports
Australia		
Icthys T2	2019	1.43
Prelude FLNG	2019	1.15
Malaysia		
PFLNG 2	2020	0.48
Indonesia		
Sengkang	2019	0.64
Tangguh T3	2021	1.21
Russia		
Yamal T3	2019	1.15
Total		**6.06**
Post-2020		
Russia Arctic LNG	2023	1.15
Mozambique	2024	4.10
Qatar expansion	2024	10.52
PNG expansion	2024	2.55
Nigeria expansion	2024	2.55
Kitimat, Canada	2025	4.46
Total		**25.33**

Source: International Gas Union

Model of a "typical" US LNG project

- Output 16 million tonnes pa (2.11 bcf/d)
- 20-year (1040 weeks, 80 quarters) lifetime
- Capital cost: $12 billion, base level of debt finance $4.8 billion
  - Real interest on debt r_B = 4.5% pa payable quarterly, fully tax-deductible
- Variable operating costs/mmbtu equal to 115% of HH
- Tax-deductible (and avoidable) random fixed costs from fixed labor, insurance, consumables, maintenance and spares, and the cost of tugs
- Corporate tax rate of 25%, payable quarterly with full loss offset, straight-line depreciation $20 b/80 per quarter for 80 quarters

Price and shipping data

- Weekly data on JKM, NBP, HH (all $/mmbtu) and Brent ($/barrel)
- Long-term contracts with NE Asian importers only, calibrated using Agerton (2017) analysis of Australia/Japan LNG trade
- 2018 GIIGNL data on LNG shipping fleet, exclude ships restricted to Nigeria and Qatar trades or below min spot trade (13,200 m^3 in capacity)
- Shipments per week varied randomly to match average plant capacity utilization of 95%
- Shipping costs estimated from Platts data

Key result: US LNG projects have substantial optionality value

- Exporter can better avoid losses and exploit upside options through destination flexibility of spot trades
  - Probability that netback price from NW Europe exceeds the netback spot price from NE Asia: $Pr(NWE_{nb} > JK_{nb}) \cong 25.65\%$
- Deep market for spot trades also allows more opportunities to fill contract trades with swaps when profitable to do so
  - Probability that a contract trade would be better filled by a spot cargo: Pr(swap profitable) ≅ 4.85%
- Firm can be forced to take *operating* losses only on contract trades
  - Probability that the best spot netback price is below the operating cost: $Pr(\max(NWE_{nb}, JK_{nb}) < 1.15HH) \cong 6.7\%$

Other results

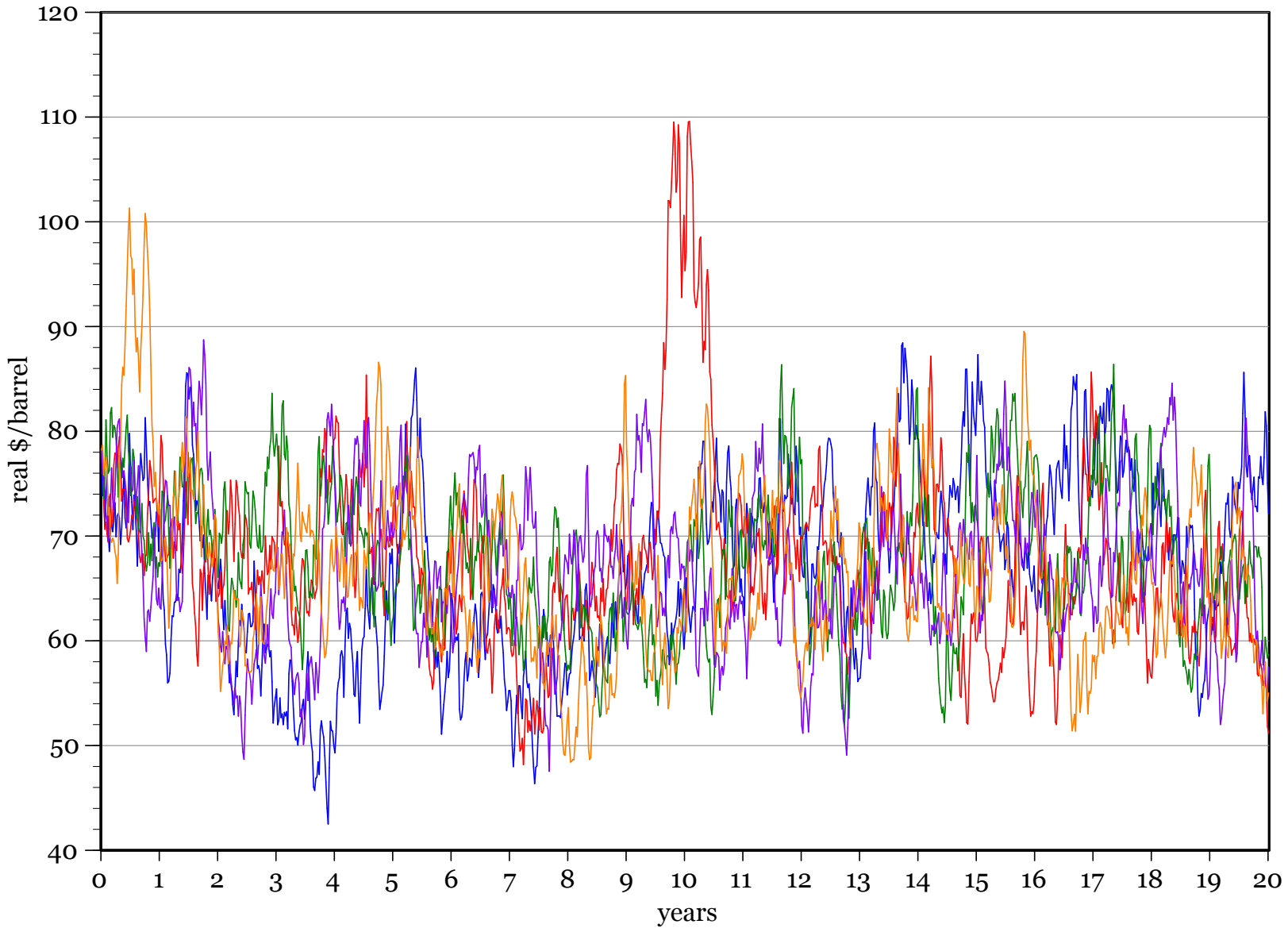
- Risk minimizing proportion of contract trade is about 60%
- Higher oil price, NBP or HH variability favor keeping less trade under long-term contract
- Higher JKM volatility and lower contract price sensitivity favor keeping more trade under long-term contract

Implications

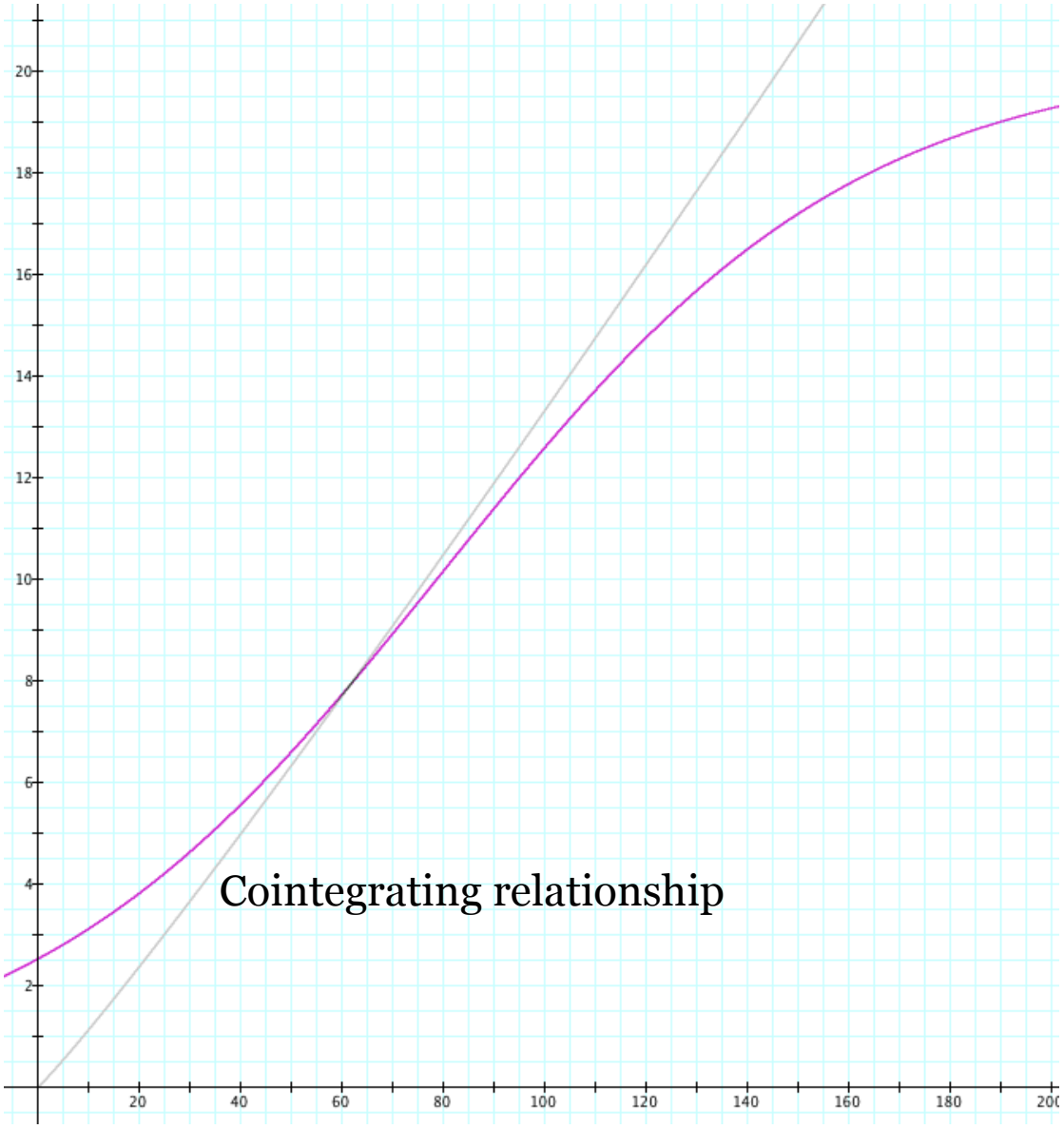
- Increasing globalization of the natural gas markets and large natural gas resources will likely keep natural gas prices around the world relatively low
  - Current very low and sometimes negative prices in West Texas and large dry gas plays like Haynesville, not to mention non-US sources
- Texas electricity prices and natural gas as a complement for wind
  - Storage versus natural gas – batteries, large hydro, pumped hydro
  - Storage requirements with VRE versus with load variation alone
- Natural gas as a competitor for coal and nuclear in the US
- LNG as an alternative fuel for transport – ships, trains, trucks
- Growing environmental opposition to natural gas as a competitor rather than enabler of VRE

Appendix

Five example 20-year *Brent* price paths



Contract S-curve and JKM cointegrating relationship



Contract S-curve

TT-NW Europe relationship to Brent