LNG Spot Prices and Long-term Contracts

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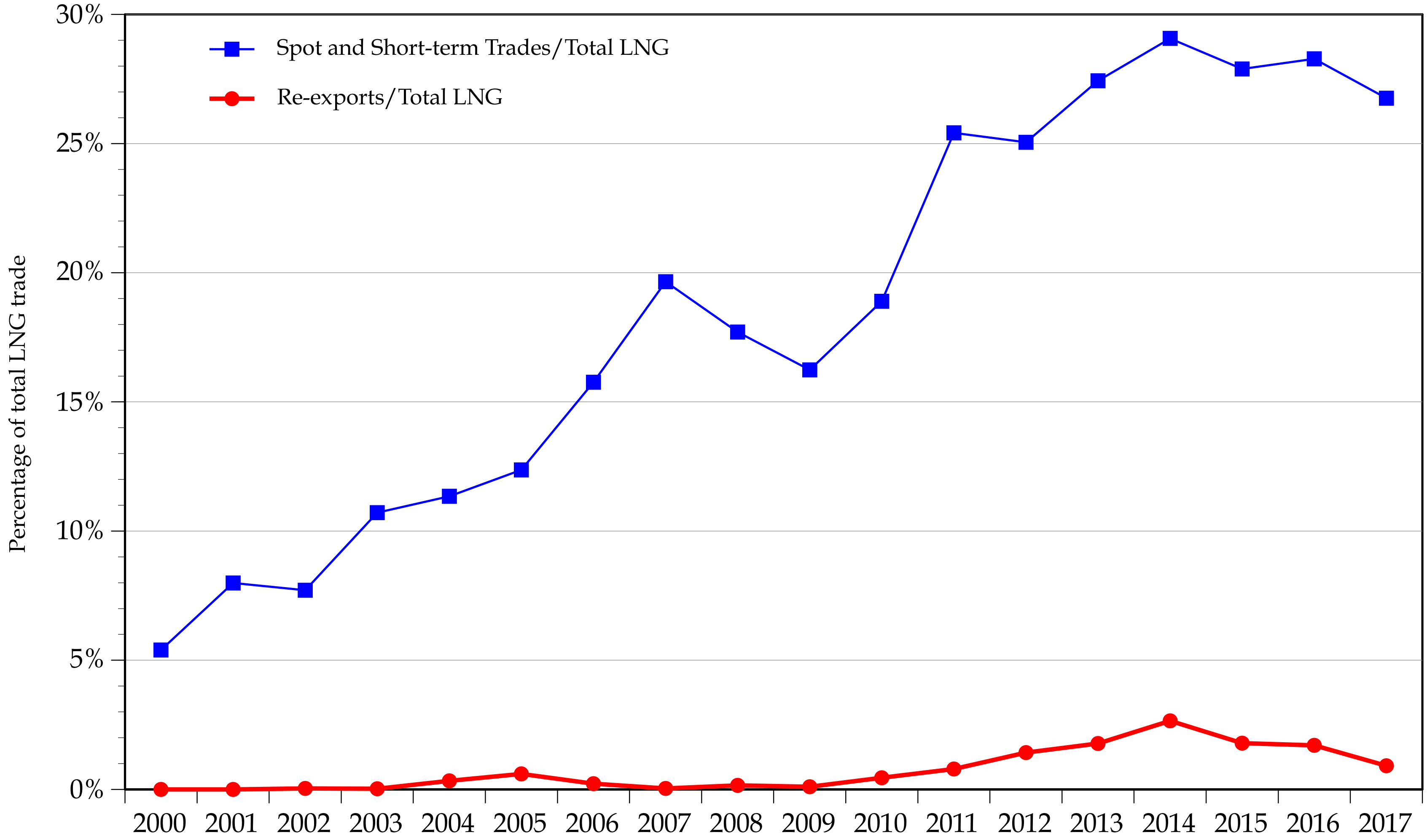
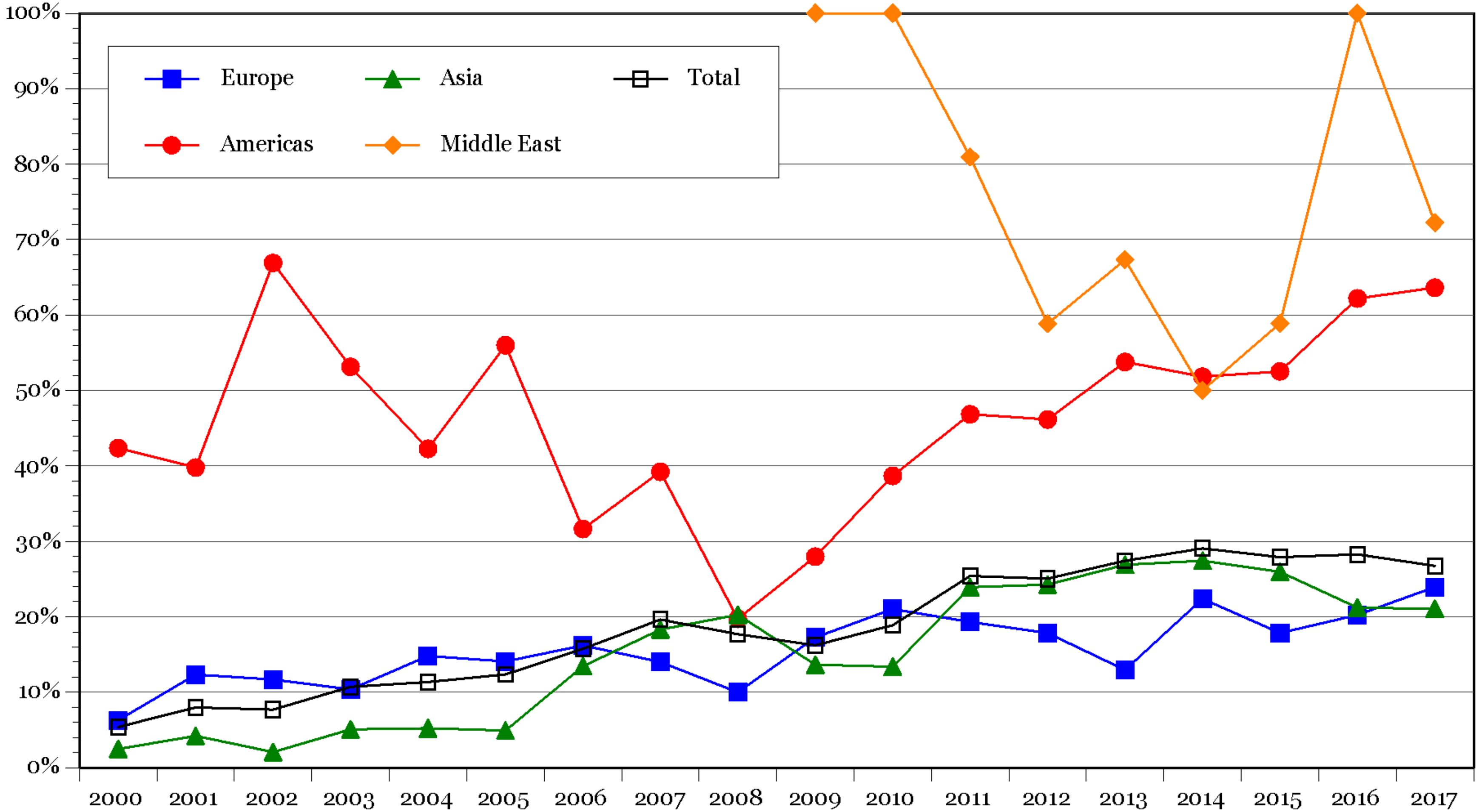
Spot and short-term (< 4 yr) LNG trade



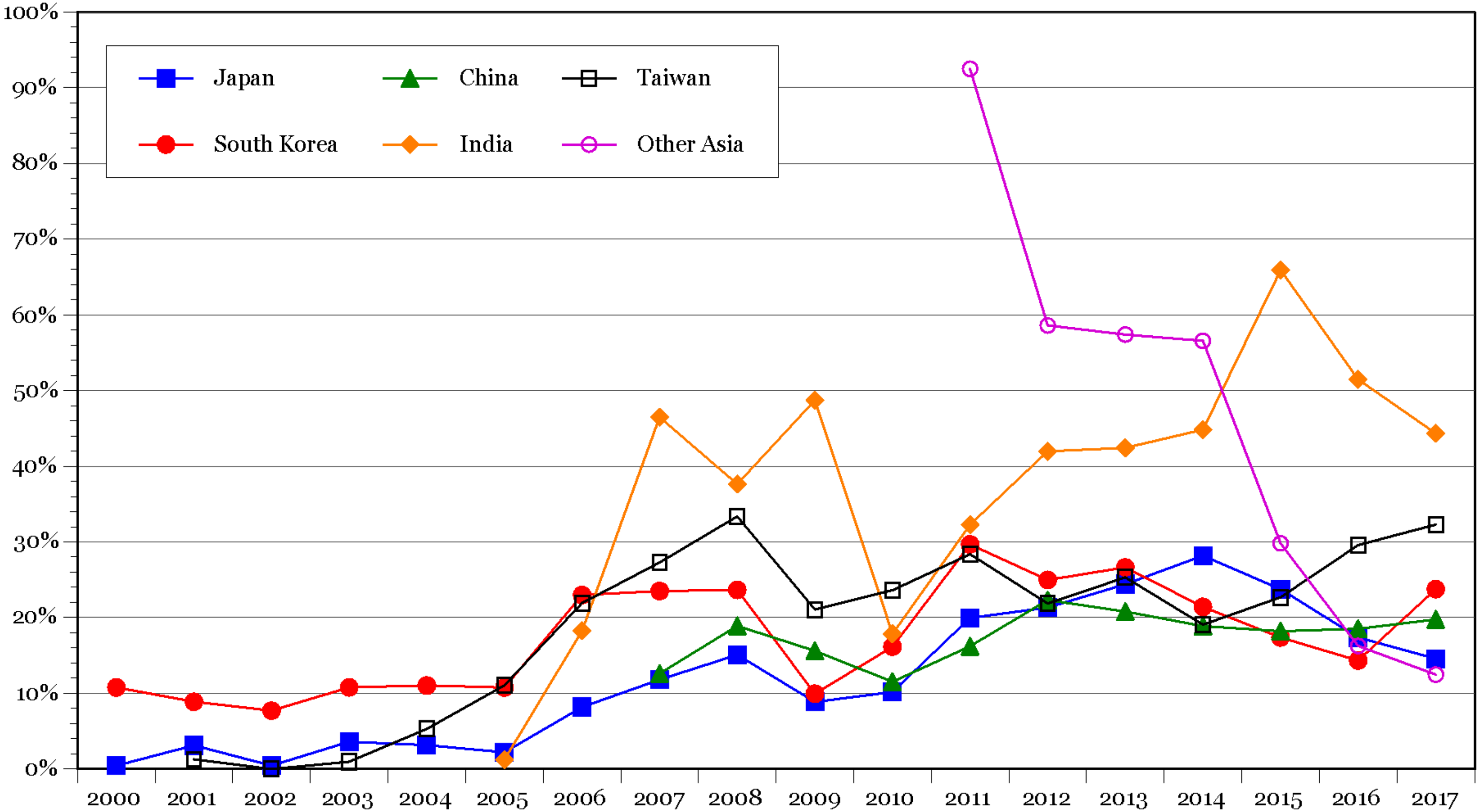
Source: GIIGNL

Regional differences in spot/short-term trade



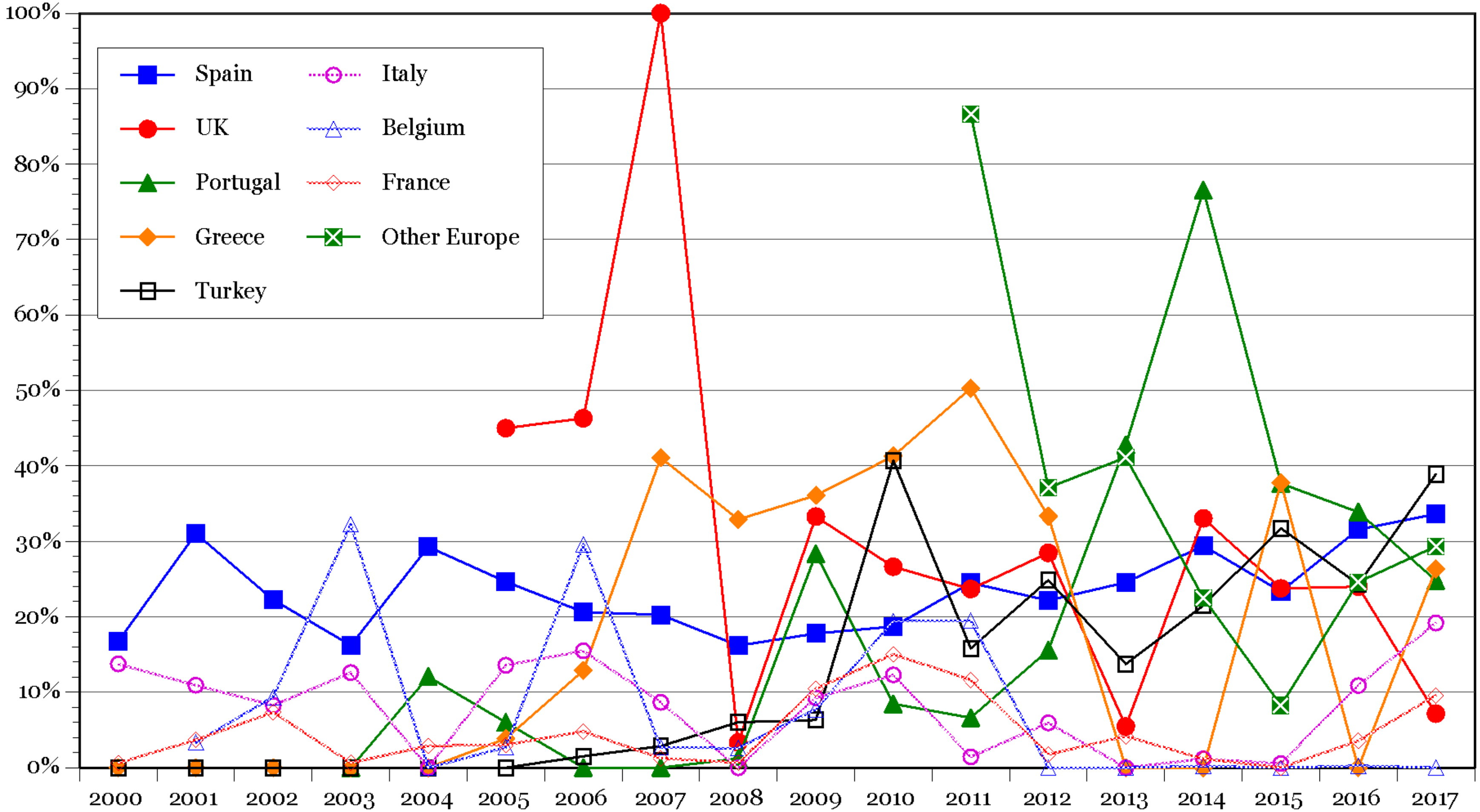
Source: GIIGNL

Spot & short-term trade in Asia



Source: GIIGNL

Spot & short-term trade in Europe



Source: GIIGNL

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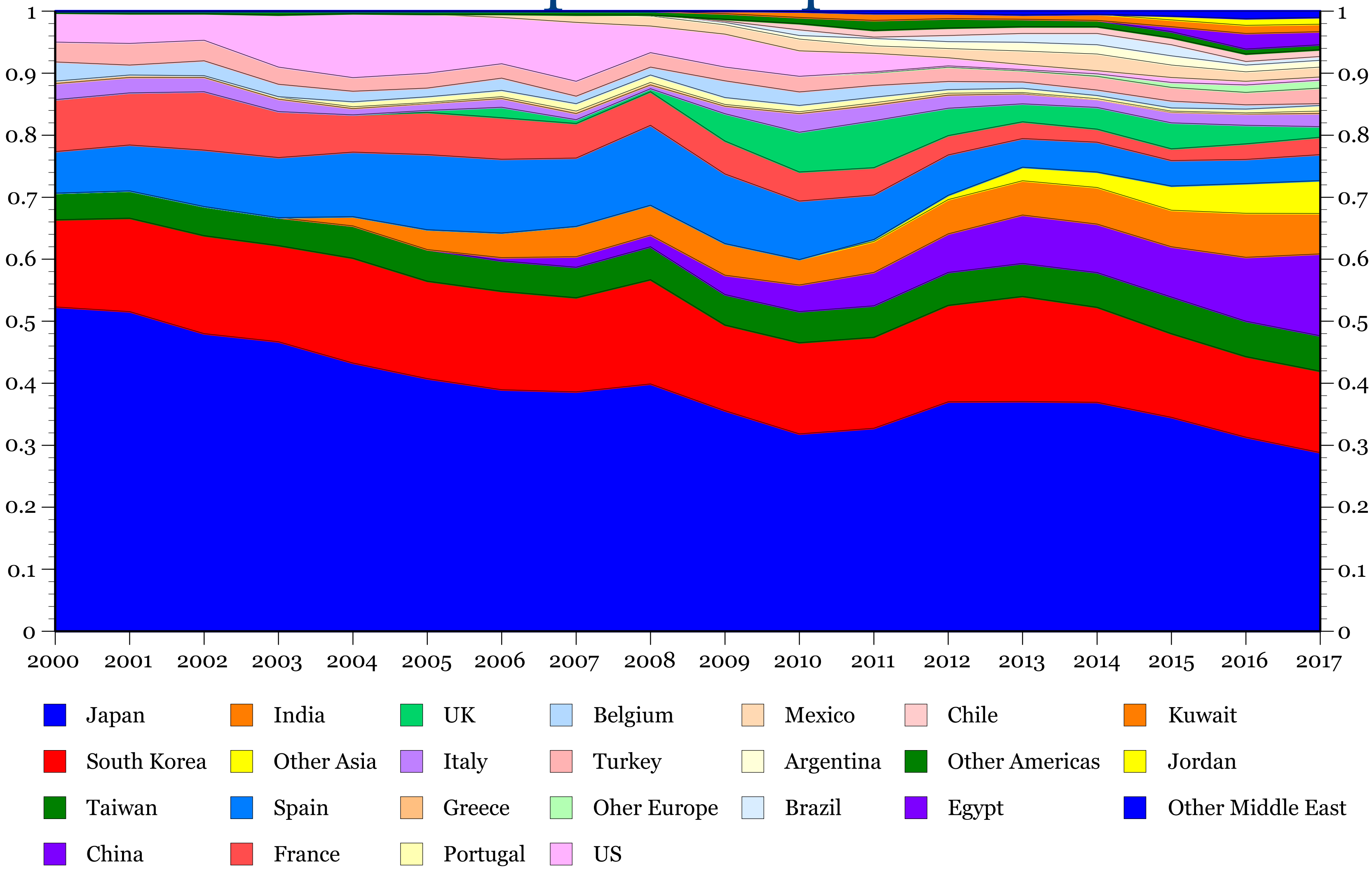
LNG Import Proportions



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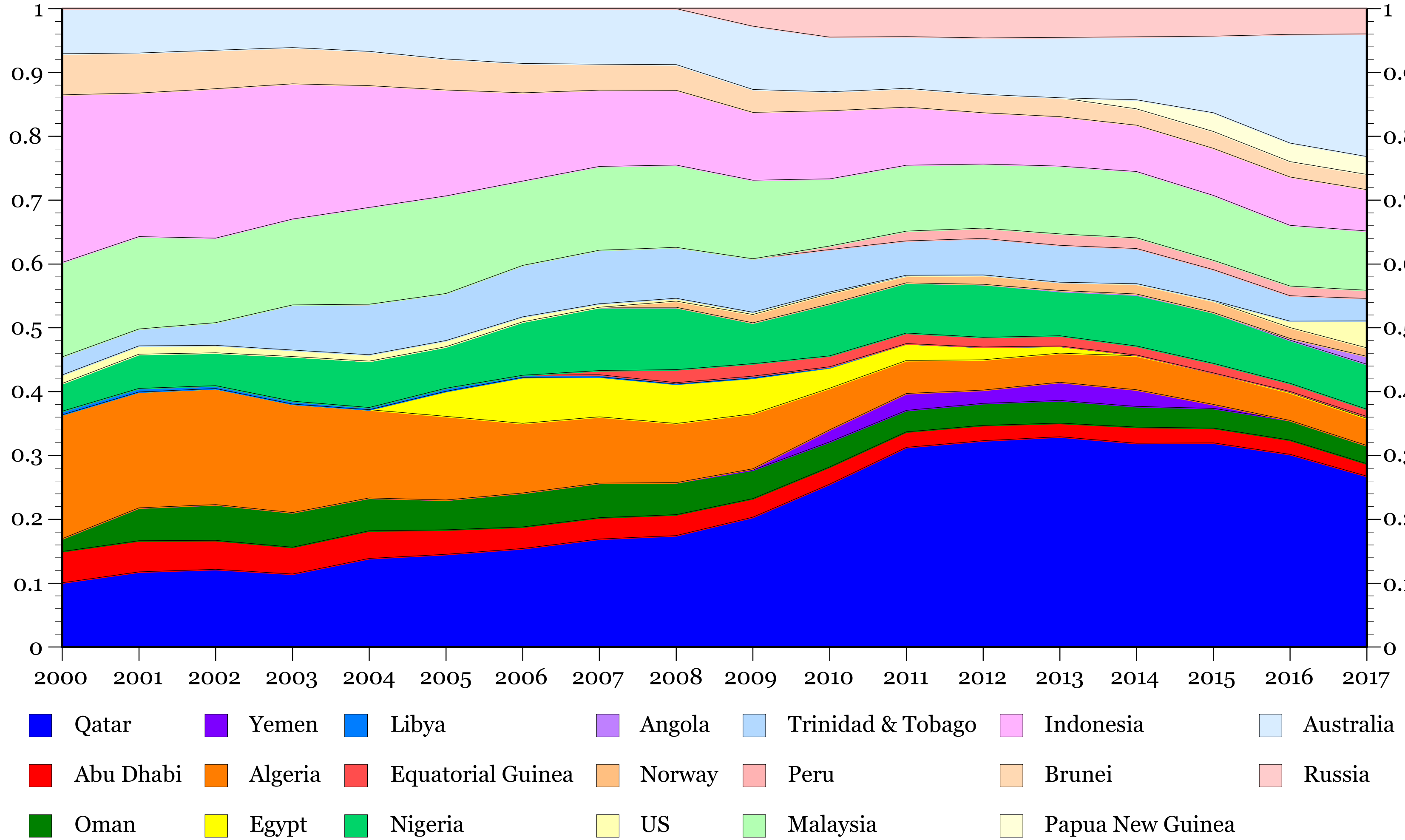
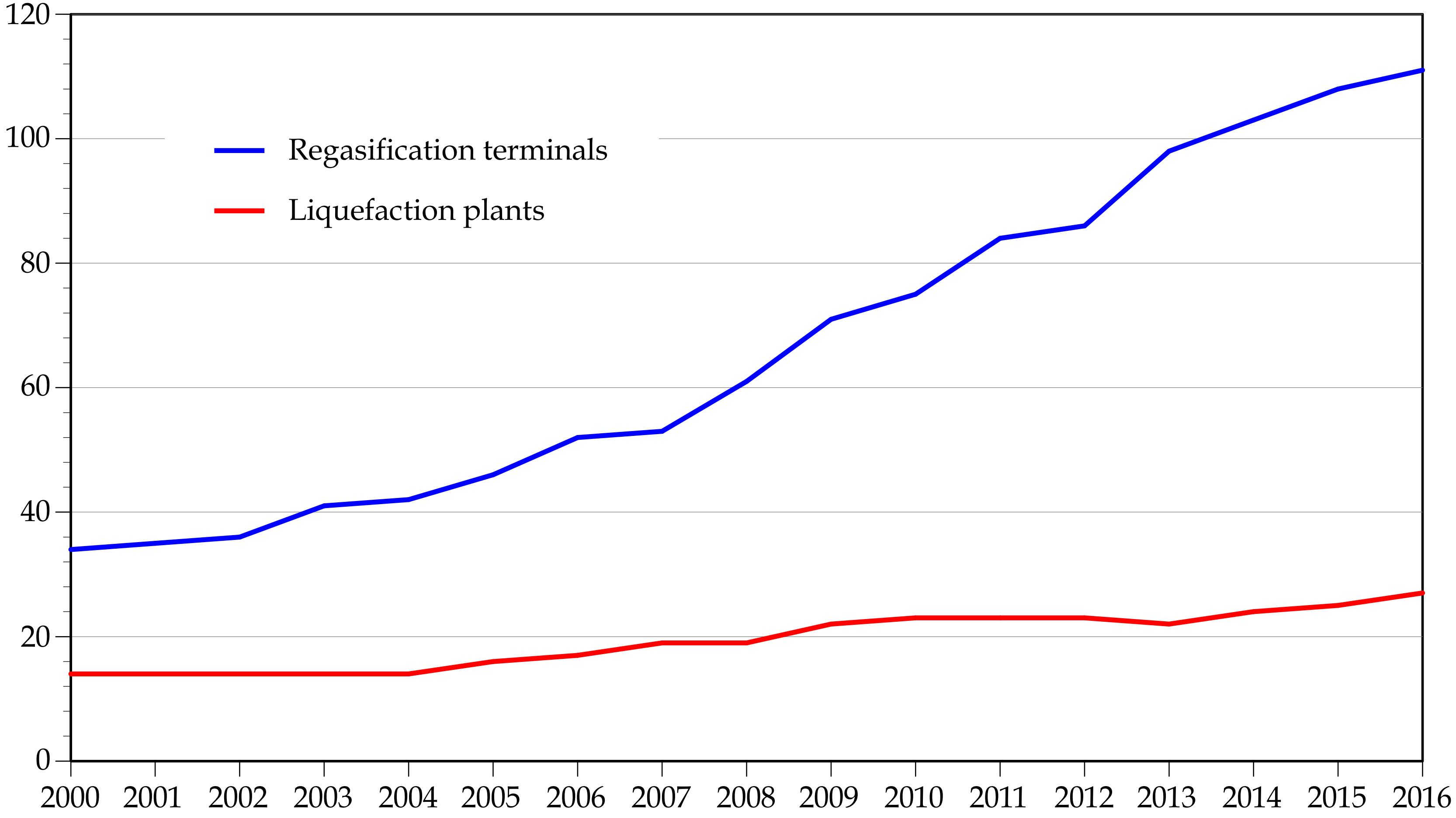
LNG Export Proportions



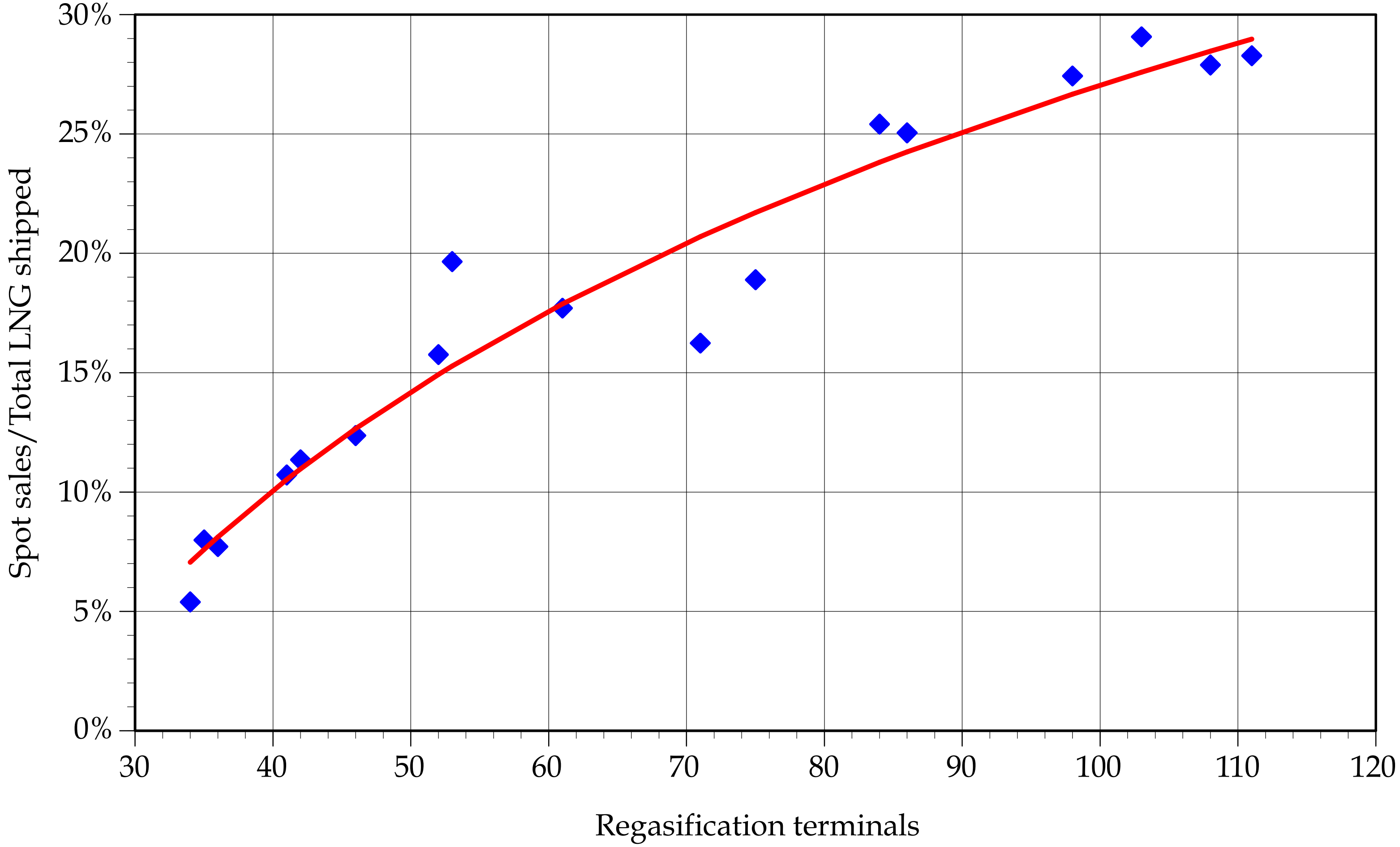
Source: GIIGNL

Increasing numbers of LNG traders



Source: GIIGNL

Spot trading and number of importers are related



Source: GIIGNL

$$\text{SpotFrac} = \underset{(0.0117)}{0.185}\ln(Regas) - \underset{(0.0486)}{0.583}; \quad R^2 = 0.9433$$

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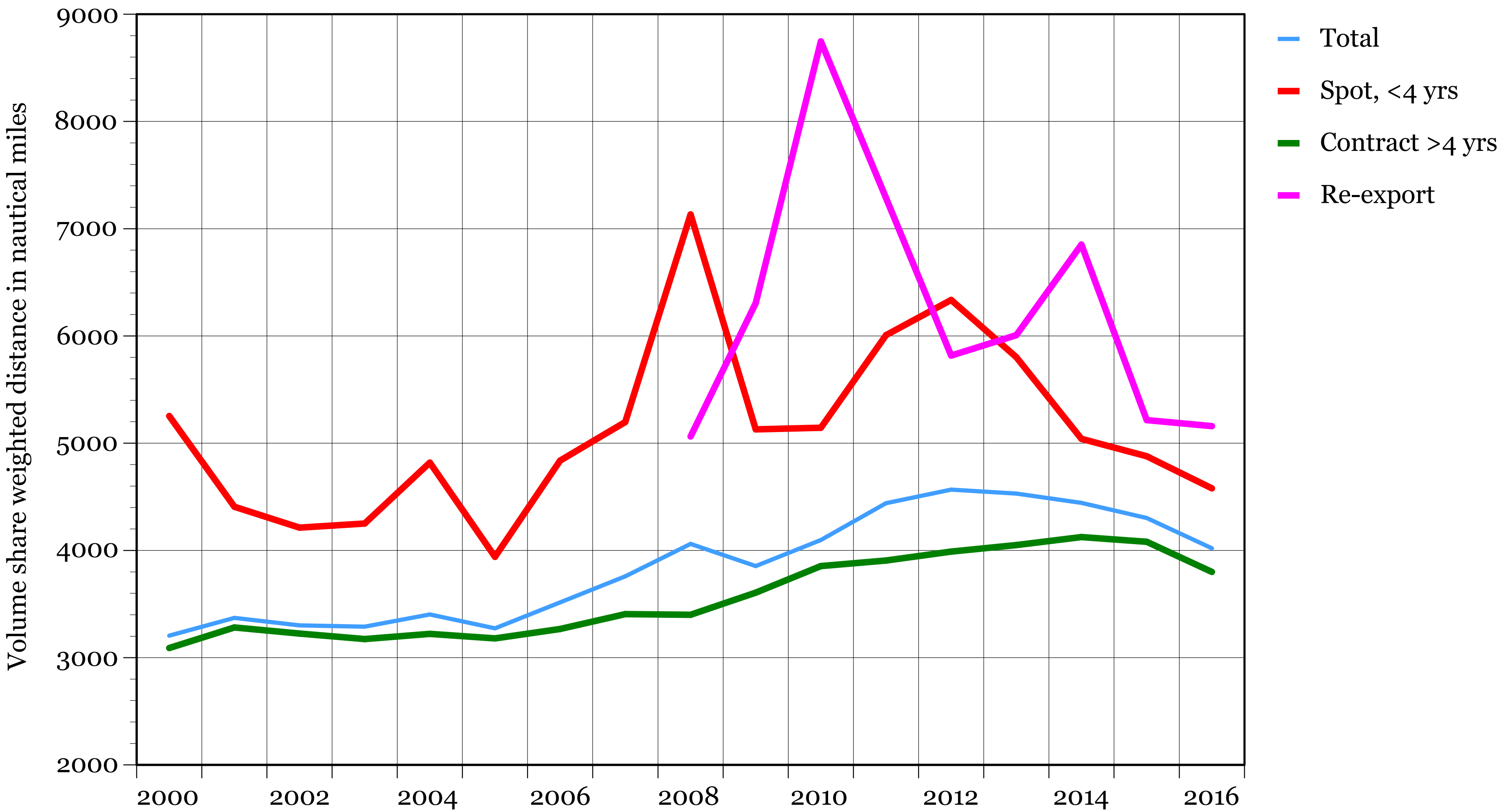
Average LNG shipping distance



Sources: GIIGNL and VesselDistance.com

Spot trading and price arbitrage linked

- LNG swaps and other spot trades increasingly exploit arbitrage opportunities
- Many regasification terminals are adding storage capacity to support arbitrage
- Expiration of long-term contracts for some early liquefaction developments has created spare capacity and without a need to finance large investments
  - More of their output is being sold short-term and spot
- Branded LNG sourced from, and sold to, many parties has increased arbitrage
- After the EU restructuring directive of 1998 (promoting competition in EU gas markets), the Commission found destination clauses anti-competitive in 2001
  - This stimulated re-export of cargoes and increased destination flexibility
  - Japan's Fair Trade Commission also ruled in June 2017 that destination clauses in LNG contracts breach competition rules
  - US LNG exports are all free from destination clauses
- Many recent contracts not only have destination flexibility but also greater volume flexibility and less than 100% off-take commitments by buyers

Long-term LNG contracts and project financing

- Key idea: A long term contract is "bankable" because its cash flow is less volatile
- Debt servicing schedule gives the firm a non-contingent liability so it needs a stable cash inflow to match
- By allowing increased leverage, a long-term contract reduces the cost of project finance
- However, a long-term contract limits the ability of the exporter or importer to exploit favorable spot market prices

Model of contracting in LNG trade

- Posit a representative LNG export project with random supply partnering NGCC power stations with random demand (the real shocks are private knowledge)
  - Exporter could sell spot at price p_X and importer could buy spot at price p_M with p_X and p_M (positively correlated) publicly known random variables
  - S is the (known and fixed) cost of shipping LNG between the parties
  - Parties are better matched to each other than to others: $\mathrm{E}p_X + S \leq \mathrm{E}p_M$
  - The spot market is well enough arbitraged that $\max(|p_X - p_M|) \leq S$
- The total amount of debt is limited by a "value at risk" type constraint
- In addition, parties may want to limit volumes under long term contract in order to retain more flexibility to exploit profitable spot market trades

Bilateral contract

- The bilateral long-term contract has the following features:
  - There is a contract volume q and contract price p paid by the buyer at the importer's location (with shipping cost S, the exporter receives $p-S$)
  - Supplier is required to deliver q unless both parties agree to a lesser amount
  - Importer taking $M<q$ when $p_X<p-S$ pays $(p-S-p_X)(q-M)\equiv\varphi(q-M)$ to the exporter
    - The fee φ compensates the exporter for the deficit between p_X and $p-S$
  - The exporter can fulfill contracts with swaps, or sell surplus production spot
  - The importer can sell q spot or supplement q with spot market purchases
- Contract terms p and q and debts are chosen to maximize $E(NPV_X)+E(NPV_M)$ subject to the value at risk constraints for both partners
- The contract also has to be incentive compatible in the sense that both parties
  - Obtain positive expected NPV from the contract; and
  - Prefer the contract outcome to expected NPV under spot market trade alone

Trading decisions under the contract

- If $p_M \geq p$ then the take-or-pay clause is irrelevant
  - Exporter will supply q at p and if importer demand is less than q, the importer will sell the surplus spot at p_X to avoid S, which will yield a loss if $p_X < p$
  - If, in addition, $p_X + S > p_M$, the exporter would prefer to sell q spot at p_X, save shipping cost S, and use a swap (at cost $p_M \geq p$) to supply importer demand up to quantity q
  - Exporter and importer may supplement q with spot market transactions
- If $p_M < p$, the importer prefers buying spot to taking q at p
  - But the take-or-pay clause means that if $p_X < p - S$ the *net* cost of buying spot would be $p_M + \varphi = p_M + p - S - p_X$
  - Hence, importer would not buy spot *unless* $p_M + \varphi < p$, that is, $p_M < p_X + S$
  - Thus, if $p_M < \min\{p_X + S, p\}$, the take-or-pay clause will be exercised, the importer will pay $\varphi q \geq 0$ to the exporter, and both will use spot markets
  - If $p > p_M \geq p_X + S$, the exporter will supply q at p and if importer demand is less than q the importer will sell the surplus spot (for a loss) at p_M

Contract trading decisions illustrated

Best spot price for buyer p_M

Best spot price for seller
plus shipping cost p_X+S

$p_X+S > p_M \geq p$
exporter uses a swap

Contract price p

$\max(p_X+S) - \min(p_M) \leq 2S$

$p_M < \min\{p_X+S, p\}$
importer exercises take-or-pay

$p > p_M \geq p_X+S$
take-or-pay prevents inefficient trade

Spot market trading regime

- Compare the contract solution to a regime where trading is not subject to any contract, and prevailing spot market prices are publicly known
  - Demand and supply shocks are private information
- If $p_M \leq p_X + S$ the importer and exporter both prefer to use spot markets
- When this is not so, define "split the difference" prices $\wp_X = (p_X + p_M - S)/2$ for the exporter and $\wp_M = (p_X + p_M + S)/2$ for the importer
- Let M_D and X_S represent the demands and supplies at $\wp_M$ and $\wp_X$
  - If $M_D > X_S$, importer must use spot market to satisfy any extra demand
  - If $M_D < X_S$, exporter must use the spot market for any extra supply
  - If $M_D = X_S$, no additional spot market transactions are desired
- For the contract to be incentive compatible, it has to be better than the outcome under this spot market trading regime for both parties

Numerical analysis

- We examined the solution for the best contract, and the spot market solution, for more than 75 spot market price distributions with *S* fixed
- For some spot price distributions, the best incentive compatible contract gave $E(NPV_X)<0$ and hence would not be feasible
  - In all these cases, the spot market solutions also gave $E(NPV_X) < 0$, so spot prices were too low to make the bilateral trade between these parties worthwhile
- The contract solution had E(NPV)>0 for both parties in a few cases where the spot market no-contract solutions had $E(NPV_X)<0$
  - In these cases, the investment projects would proceed under a contract, but would not be feasible without a contract
- The average combined surplus is about 30% higher under the contract solution
  - Main reason: the contract allows the investment projects to carry more debt
  - But the benefits of extra debt exceed the final gains in NPV, implying there are some offsetting losses from inefficient price signals in some contract trades

Effect of changes in mean prices on contract terms

- Key result: Making the partnership less valuable by reducing the gap between p_X and p_M while holding p_X fixed
  - Decreases contract price p and volume q
  - Greatly reduces the premium of the contract over the spot solution
  - Greatly increases the amount of spot market trading by both parties, but especially by the importer
- Indexing: Shifting p_X and p_M distributions by the same amount z
  - Raises optimal contract price 85–90% of z
  - Bilateral trade becomes more desirable, so contract volume rises and importer spot trading declines; effect on exporter spot trades is ambiguous
  - The exporter, whose costs are unrelated to the price increase, benefits substantially

Effects of changes in spot price variability

- An increase in the variability of p_X and p_M holding the variability of the gap v between them fixed increases the desirability of the long-term contract
  - The *additional* debt under the contract rises as cash flows become more variable
  - Corollary: Lower spot price variability would erode the value of long term contracts
- Except when the mean value of v is high and the variability of v is low, the proportion of spot trading relative to contract volume increases with both variability of the gap v and the variability of p_X
  - Higher variability of especially import spot prices increases the option value of spot market trades
  - Corollary: Lower geographic dispersion in spot prices would tend to reduce spot trading as a proportion of long term contract volume
- Effects of price variability on contract terms p and long term contract volume q are highly non-linear

Effects of market deepening

- The above discussion relates to the choices of individual producers and consumers of LNG
- As more, and more widely dispersed, producers and consumers enter the market we would expect:
  1. Smaller gaps between the *mean* spot prices available to exporters and importers
  2. Lower variability in the gap between the spot prices available to exporters and importers
  3. Lower variability in spot process overall as shocks are spread more widely across the globe lessening the local impacts of each one
- From the analysis, (1) and (3) should increase spot market trading while (2) would tend to decrease it
  - Overall, a deeper spot market is likely to increase spot trading

Expectations and multiple equilibria

- Endogenous changes in expectations about market structure can reinforce and amplify the effects of the changes in exogenous factors
- Firms have to sequence investment and trading decisions and in doing so can follow two broad strategies:
  1. Contract more long-term trading partners before investing
  2. Invest early with few, if any, long-term trading partners
- Strategy 1 will allow lower cost financing
- Strategy 2 leaves the firm free to exploit more new or ephemeral trading opportunities
- Endogenous element: Effectiveness of search for trading partners depends on the number of available potential partners
- If parties switch from strategy 1 to strategy 2, it becomes more attractive for new entrants to expect strategy 2 to be more successful
- Such an effect can explain a rapid transition to spot trading as has occurred in other commodity markets

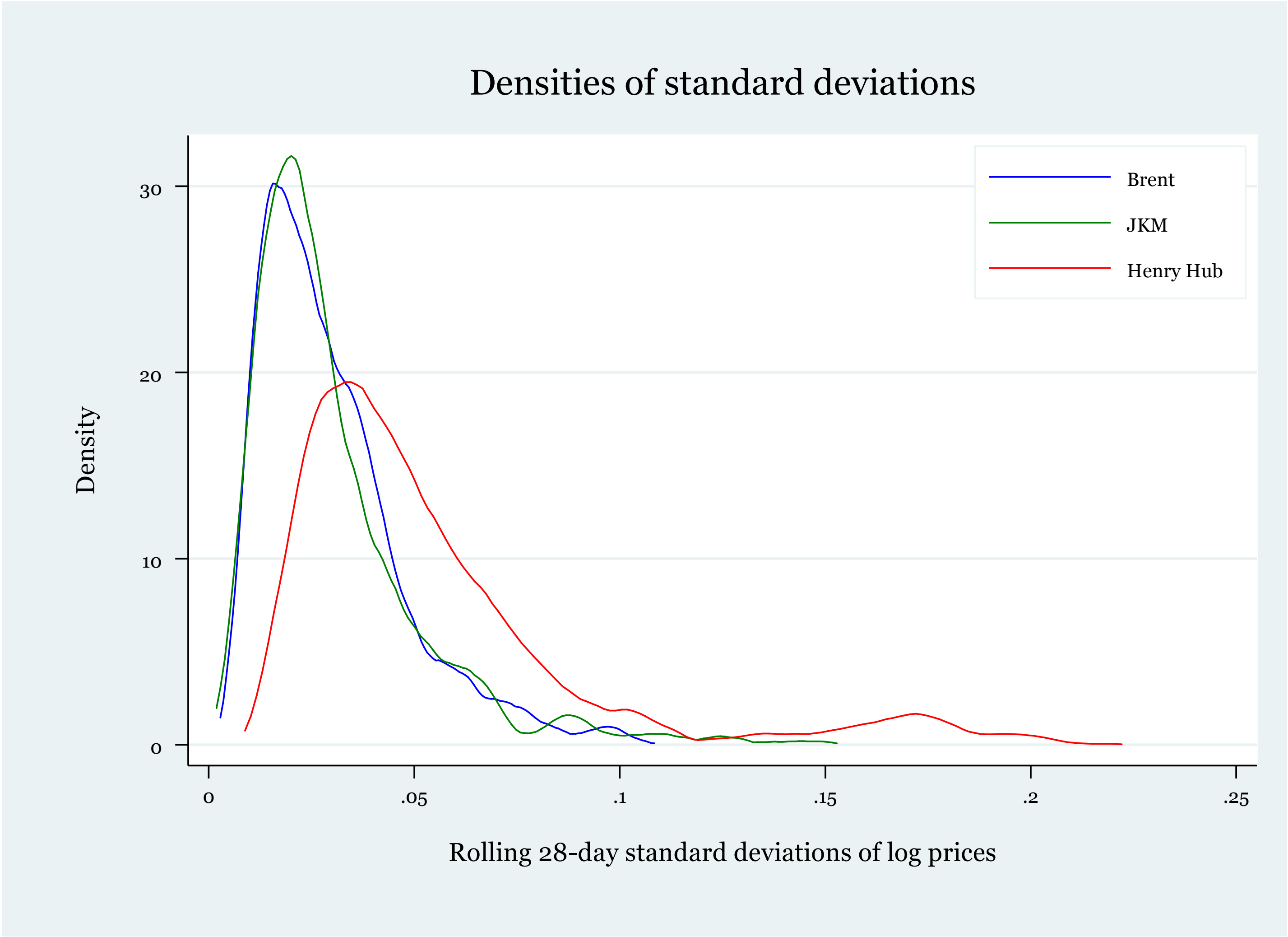
Effects of US exports on LNG trade

- US plants require less investment than traditional liquefaction projects
- US exports will further encourage spot trade growth and price arbitrage
  - Most exports are under a tolling arrangement with the feed gas price tied to Henry Hub, increasing linkages between international natural gas prices
  - Branded LNG buyers, with trading strategies explicitly based on arbitraging price differences, are prominent buyers of US exports
  - Future co-location of regasification and liquefaction facilities in the US with pipeline connections to extensive storage and a deep market will facilitate short-term arbitrage
- Nevertheless, future greenfield developments, such as in East Africa, are likely to need long-term contracts to support financing of large Capex

Indexing in long-term contracts

- Energy *relative* prices are much more stationary than individual energy prices
- *Oil* prices tend to be the *most exogenous* energy price in markets where both prices are free to fluctuate independently
- The model suggested 85–90% indexing of LNG to general energy price movements, which is close to what we see in oil-indexed contracts
- LNG prices could also be indexed to highly liquid gas pipeline hub markets with well-developed derivatives markets such as Henry Hub or NBP but:
  - Indexing to natural gas hub prices may replace commodity basis risk with geographical basis risk
  - While US natural gas prices recently have been little affected by the foreign exchange value of the $US, this may change after US LNG is traded
  - Natural gas prices are more volatile than oil prices

Relative volatilities of Henry Hub, Brent and JKM



Summary comments

- Imminent supply expansions may keep LNG prices low, encouraging LNG imports and more widespread use of natural gas
- More elastic natural gas supply and demand, and intermediaries providing hub services and having access to storage, should reduce price volatility
- Gaps between spot prices in different locations should decline
- Growth in spot trading may reduce volumes under contract and raise spot market participation, further raising spot market liquidity
- Spot market trades from contracted parties should continue to increase while long-term contracts become more flexible
- Gas price indexes from deep natural gas markets will be used to index long-term LNG contracts – not least because of US exports indexed to Henry Hub
- Increased spot and short-term trading may favor lower capital cost projects
- *Nevertheless*, large greenfield projects required eventually may need long-term contracts to underwrite their financing

Appendix

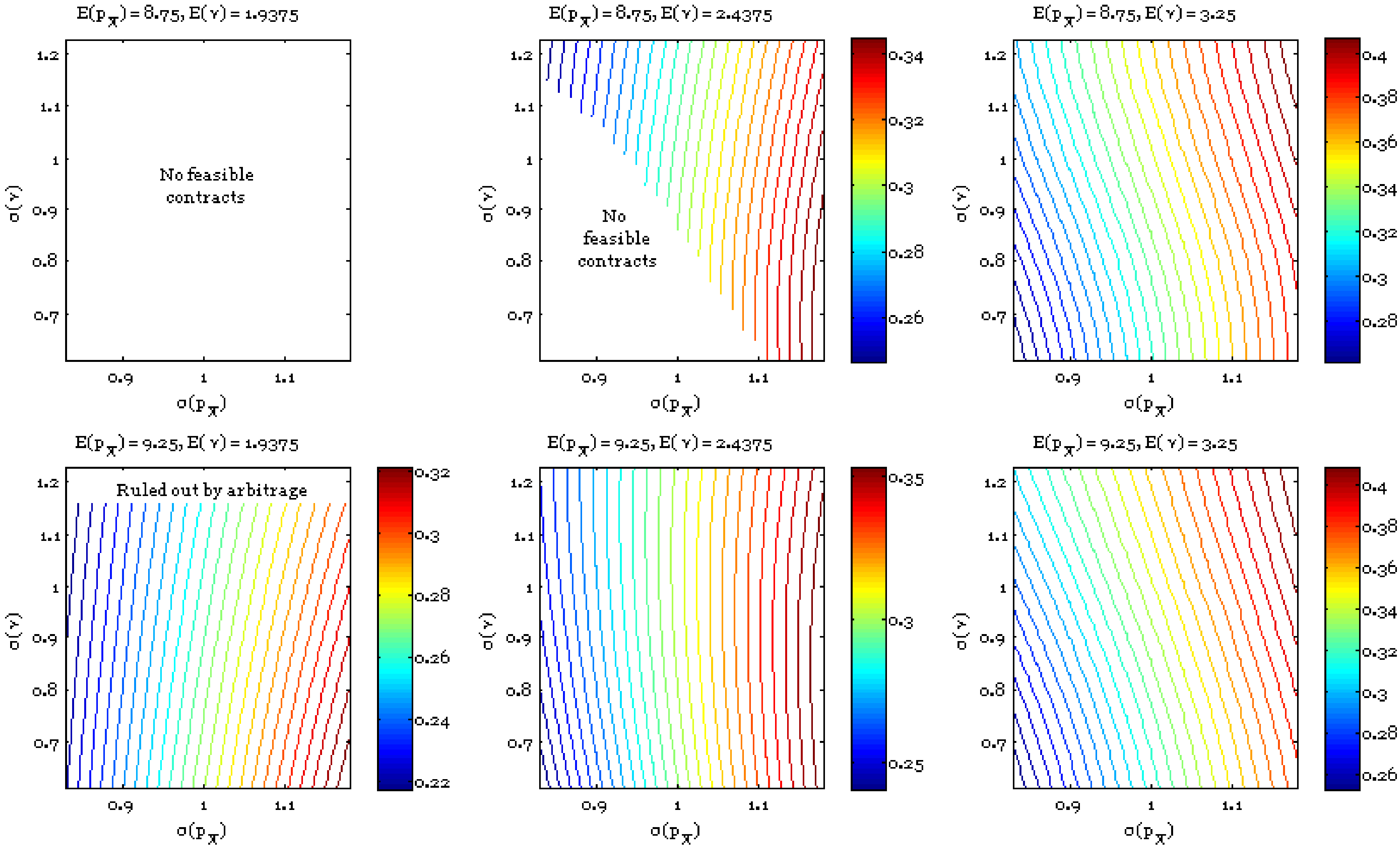
Numerical values in the contracts analysis

- Distributions of p_X and p_M were symmetric beta
- Shipping cost S was taken fixed at \$1.25 per mmbtu
- Ep_X = \$8.75 or \$9.25 per mmbtu, with $\sigma(p_X)$ = \$0.82, \$1.00 or \$1.19
- Ep_M took 4 values from \$11.19–\$12.50, and $\sigma(p_M)$ 18 values from \$1.03–\$1.71
- Correlation between p_X and p_M ranged from 0.55 to 0.89, average = 0.72
- $\Pr(p_M < p_X + S)$, when it is efficient for the two parties not to trade, ranged from 0.0 to 0.296 and averaged 0.089

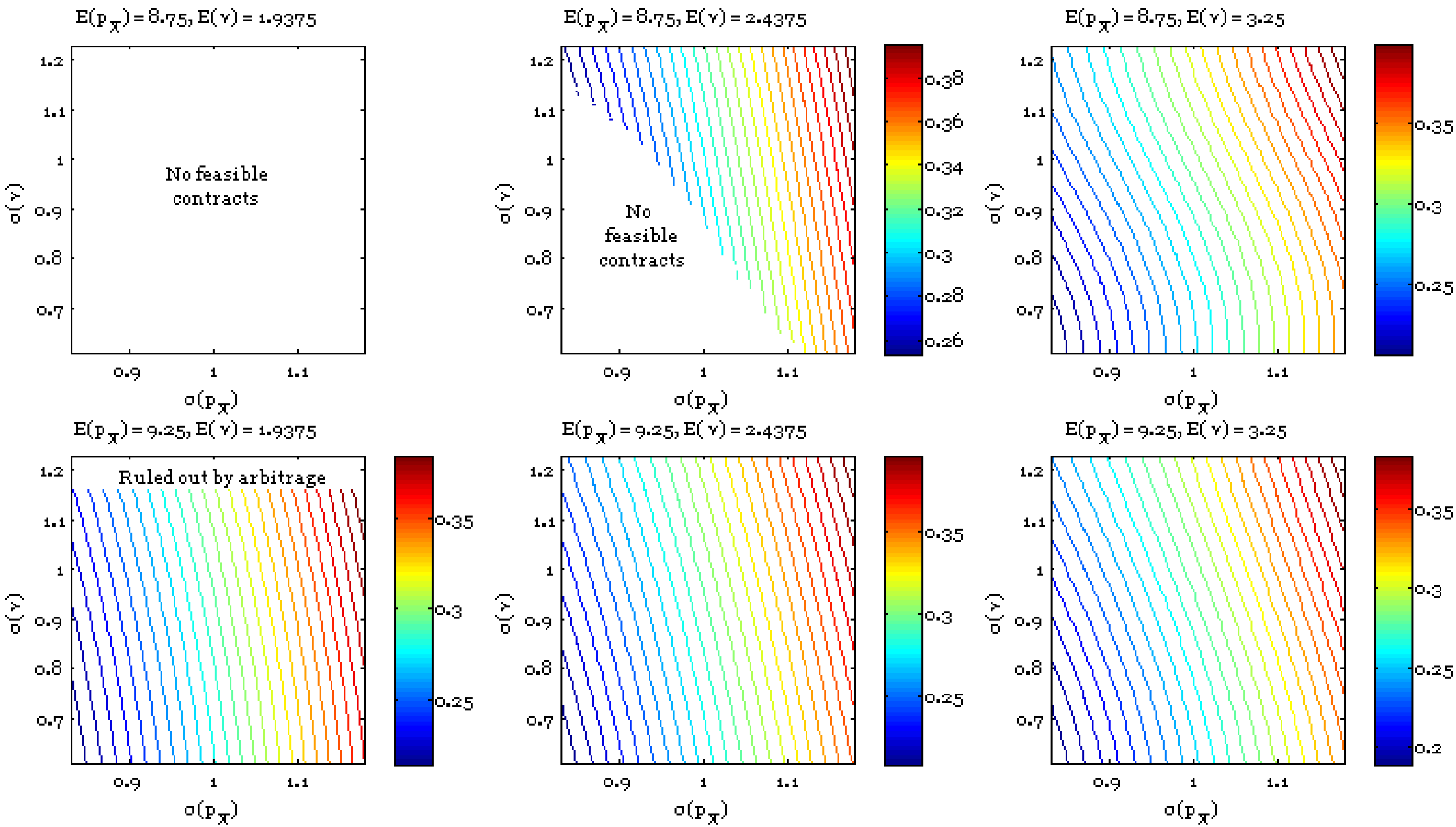
Average values of key variables

$E(p_X)$	8.75		9.25		
$E(\nu) = E(p_M) - E(p_X)$	2.4375	3.25	1.9375	2.4375	3.25
Number of distributions	12	15	15	18	15
Contract price *p* ($/mmbtu)	10.68	10.97	10.90	11.10	11.42
Contract quantity *q* (10^6 mmbtu/year)	223.09	229.59	230.90	234.57	239.35
$E(NPV_X)$ under contract ($ m)	45.10	487.06	463.35	749.45	1260.92
$E(NPV_X)$ full information ($ m)	−312.28	178.57	49.19	287.61	610.37
$E(NPV_X)$ public information ($ m)	−434.10	105.19	39.87	338.46	865.71
$E(NPV_M)$ under contract ($ m)	1547.12	881.00	1233.85	785.26	137.94
$E(NPV_M)$ full information ($ m)	1662.83	1121.91	1352.58	1016.82	660.49
$E(NPV_M)$ public information ($ m)	1533.69	792.61	1205.90	731.30	55.10
B_X under contract ($ m)	5176.72	5490.05	5430.67	5634.68	6004.37
B_X full information ($ m)	3827.87	4435.16	4135.53	4375.31	4748.26
B_X public information ($ m)	3612.66	4016.04	3997.10	4157.08	4492.09
B_M under contract ($ m)	3162.26	2785.63	2966.36	2724.92	2308.40
B_M full information ($ m)	3277.38	3292.48	2917.39	2875.80	2850.60
B_M public information ($ m)	2620.52	2350.06	2500.51	2285.66	1982.46
Contract premium relative to *PI*	30.97%	34.26%	26.54%	30.18%	34.04%
Importer spot net purchases	50.12	15.96	53.34	27.07	1.10
Exporter spot net sales	28.48	9.83	42.86	26.63	11.66

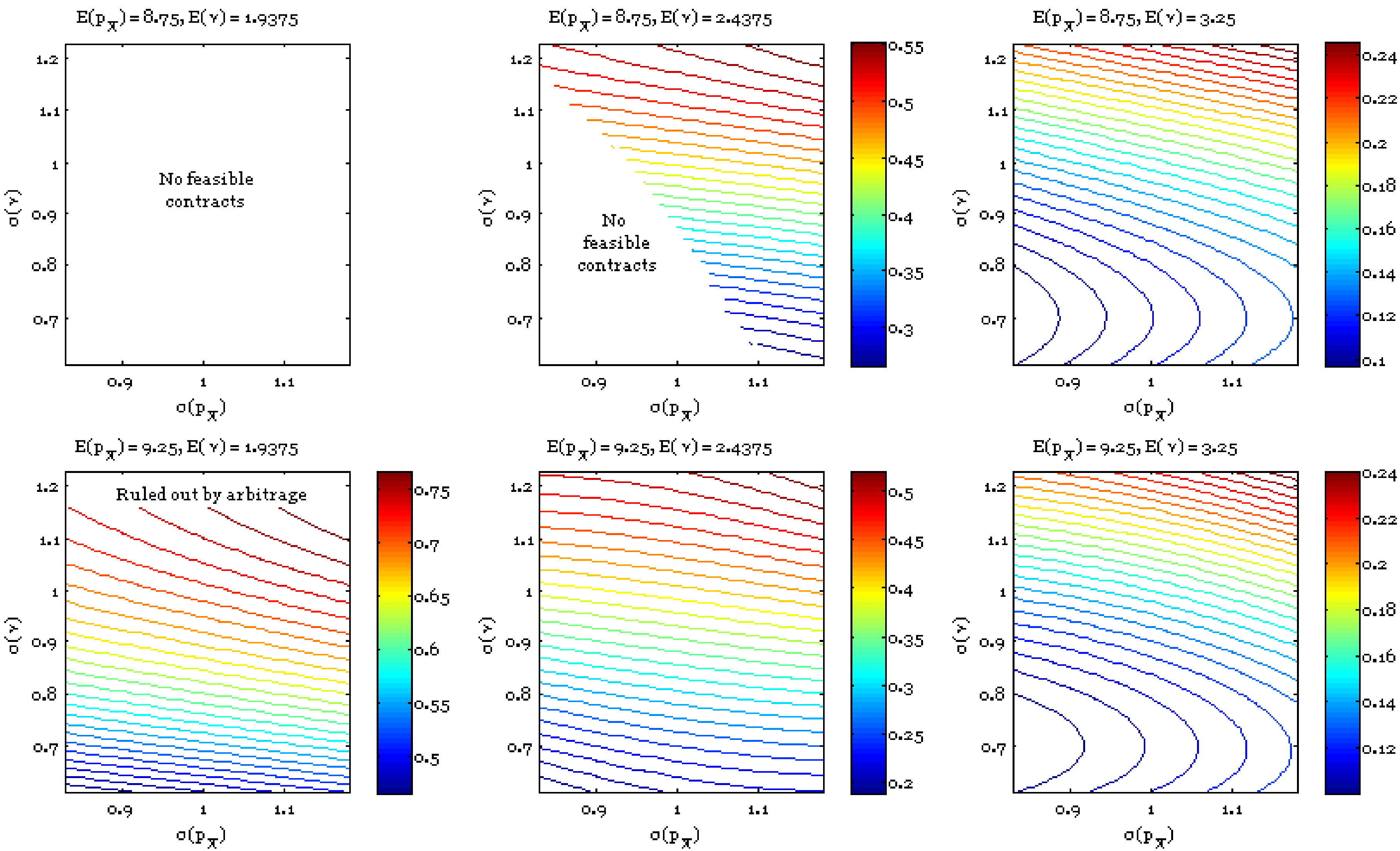
Contract premium over spot trading equilibrium



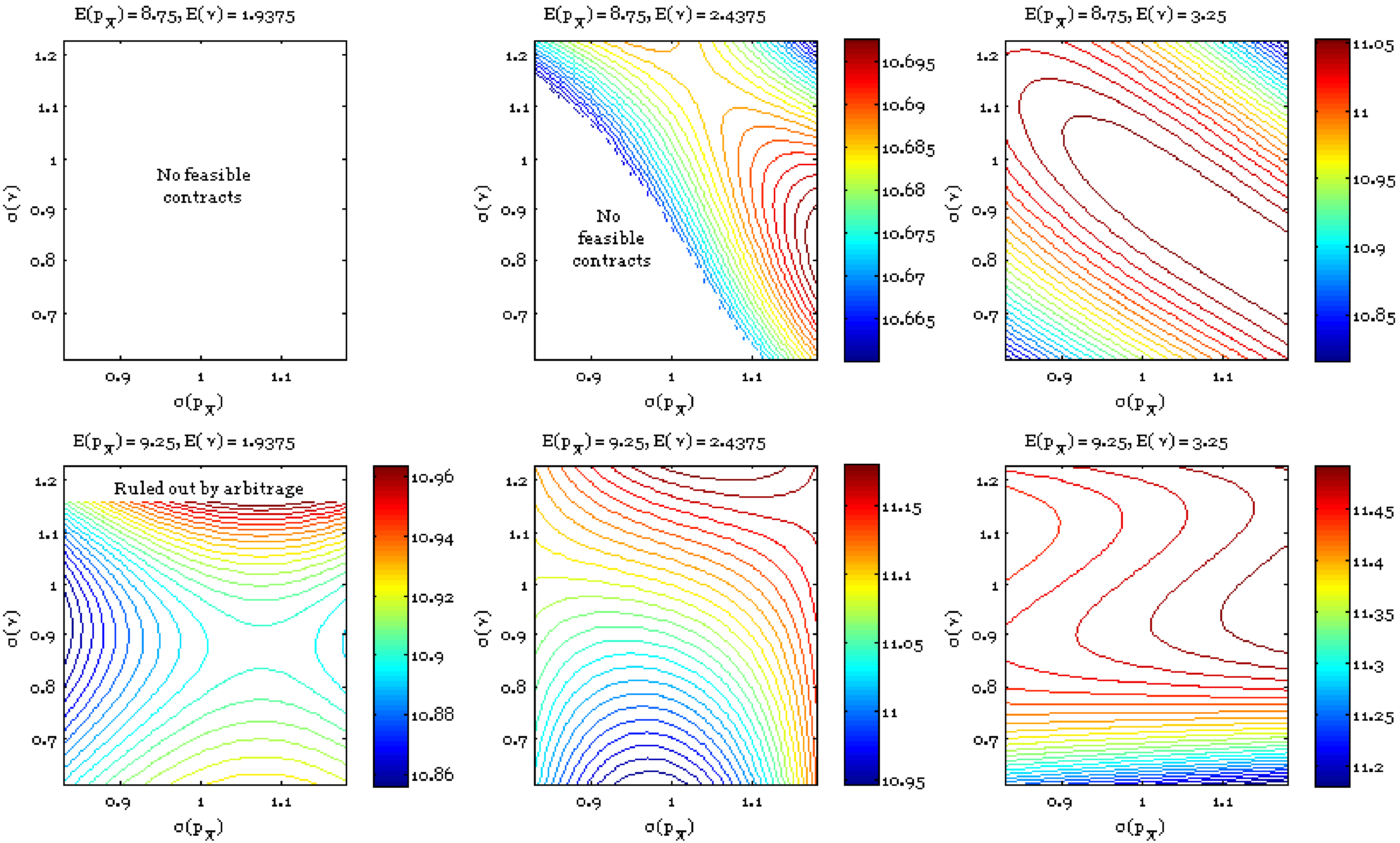
Extra debt under contract solutions



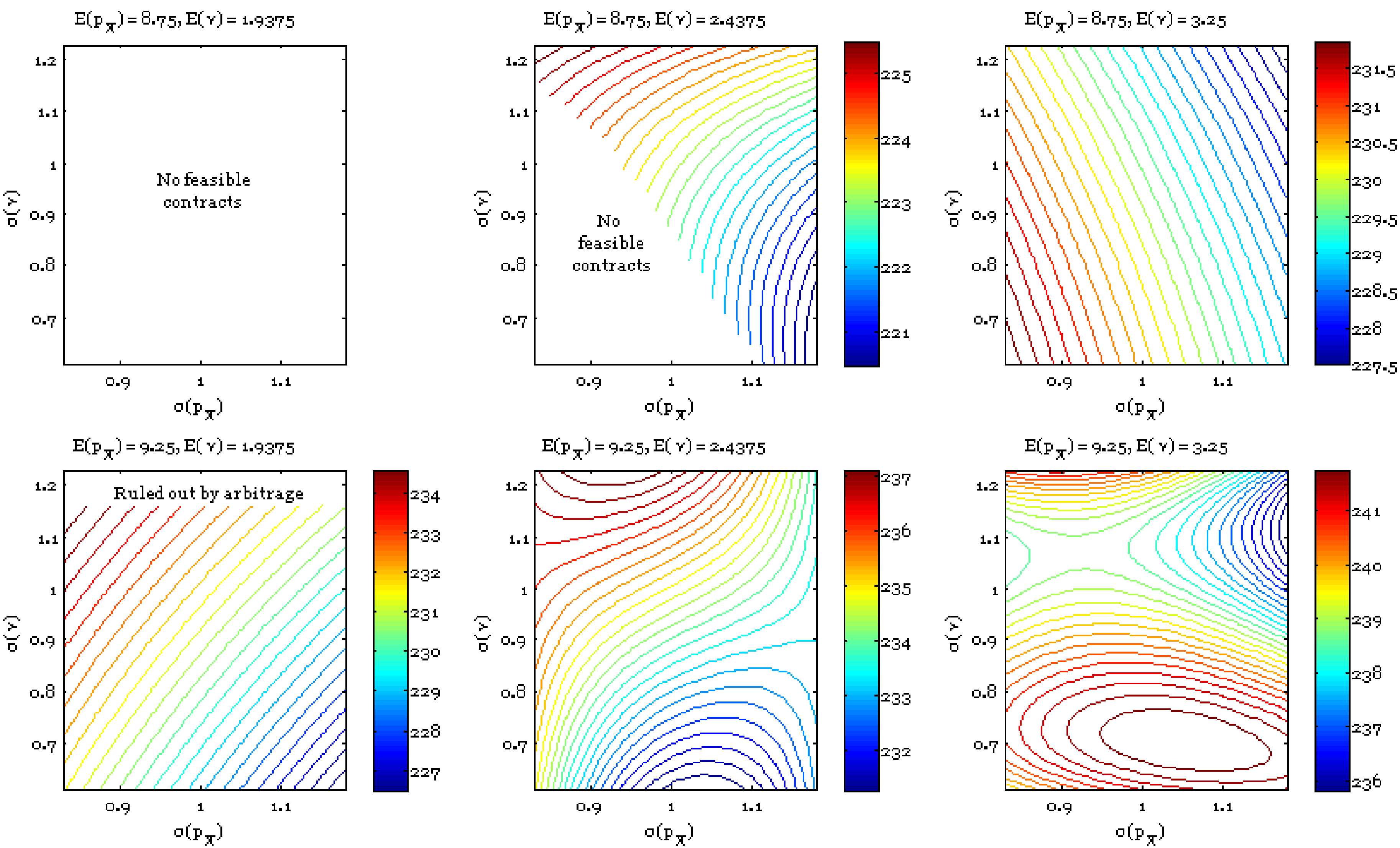
Gross spot trades relative to contract volumes



Contract prices ($/mmbtu)



Contract volumes (106 mmbtu/year)



Approved/Proposed US LNG export terminals

Terminal status and location	Capacity as % 2017 LNG exports
Operational	
Sabine Pass (trains 1–4), LA	7.24
Cove Point, MD	2.12
Under construction	
Sabine Pass (train 5-6), LA	3.62
Hackberry, LA	5.43
Freeport, TX	5.53
Corpus Christi, TX	5.53
Elba Island, GA	0.91
Sub-total operational or under construction	**30.39**
Approved, not under construction	
Hackberry, LA (expansion)	3.65
Lake Charles, LA (Southern Union)	5.69
Lake Charles, LA (Magnolia)	2.79
Golden Pass, TX	5.43
Operational, under construction, or approved	**47.95**
13 terminals with pending applications – additional capacity	61.14
3 terminals in pre-filing – additional capacity	9.4

Note: At average annual growth of LNG market since 2000 of 6.4%, it would take 11.2 years for the market to double in size

Other projects "under construction" 2018–2020

Terminal and location	Start year	Capacity as % 2017 LNG exports
Australia		
Icthys	2018	3.07
Wheatstone T2	2018	1.54
Prelude FLNG	2018	1.24
Malaysia		
PFLNG 2	2020	0.52
Indonesia		
Sengkang	2018	0.17
Tangguh T3	2020	1.31
Cameroon		
Cameroon FLNG	2018	0.83
Russia		
Yamal T2	2018	1.90
Yamal T3	2019	1.90
Total		**12.47**
Qatar expansion	2024	**7.94**

Source: International Gas Union

US LNG Exports February 2016–May 2018

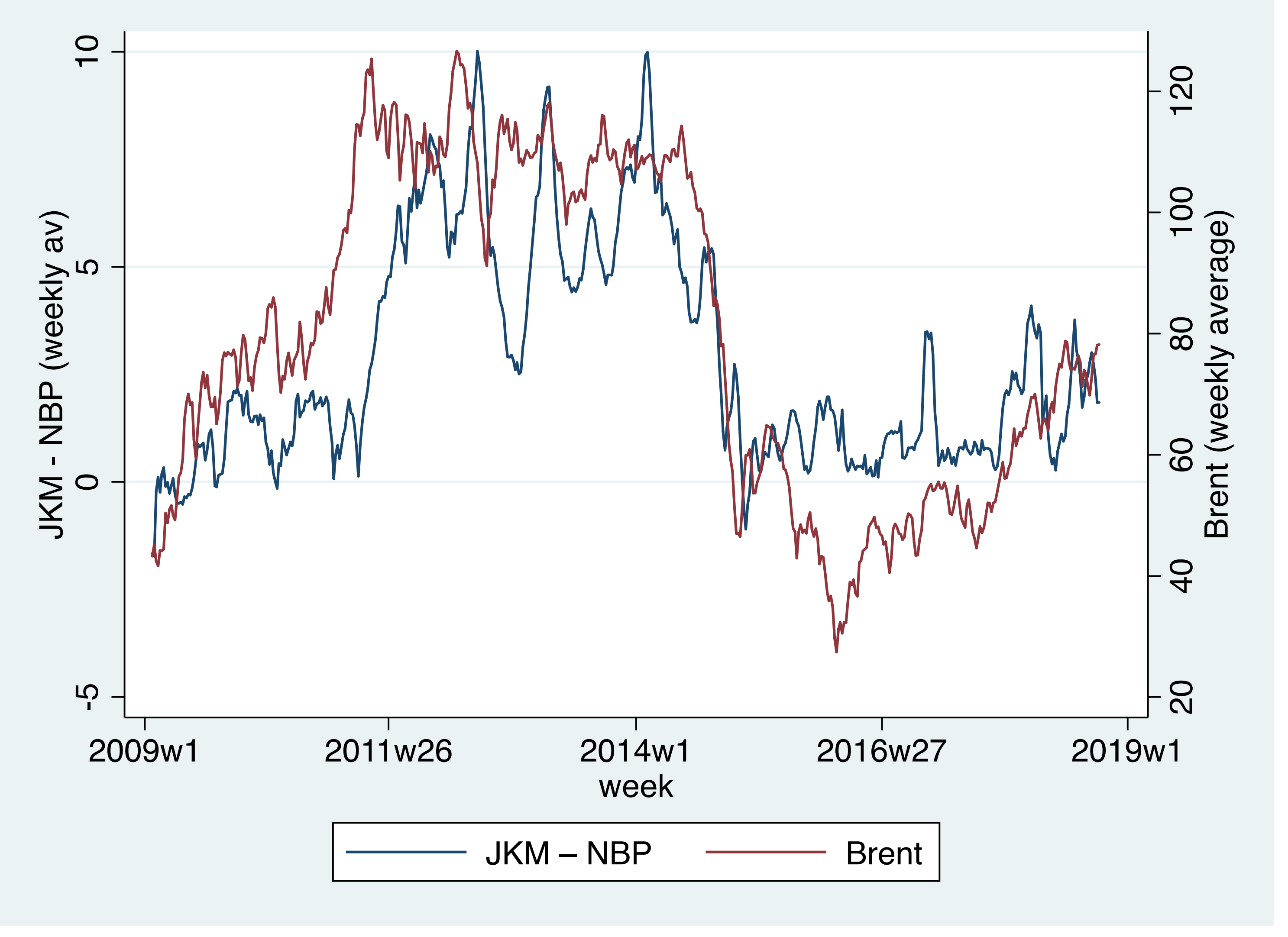
Country of destination	Quantity (MT)	% of total US LNG exports
Mexico	5.06	18.8
South Korea	4.86	18.1
China	3.69	13.7
Japan	2.03	7.6
Chile	1.51	5.6
Jordan	1.38	5.1
India	1.29	4.8
Argentina	0.96	3.6
Turkey	0.83	3.1
Brazil	0.71	2.6
Kuwait	0.69	2.6
Spain	0.66	2.5
Portugal	0.54	2.0
Egypt	0.35	1.3
U.A.E.	0.34	1.3
Pakistan	0.33	1.2
Taiwan	0.32	1.2
Dominican Rep.	0.30	1.1
Others (12 countries)	1.00	3.7
Total	**26.86**	

Typical LNG shipping costs ($US/MMBTU), 2015

Origin	Japan/ Korea	S China/ Taiwan	West India	SW Europe	NW Europe	NE USA	Argentina	Brazil
Sakhalin	0.15	0.22	0.57	1.20	1.26	1.60	0.96	1.33
Australia	0.32	0.29	0.36	0.98	1.08	1.11	0.74	0.88
Mid-East	0.58	0.50	0.15	0.71	0.80	1.08	0.74	0.85
Peru	0.81	0.92	1.03	0.82	0.85	0.93	0.34	0.51
Nigeria	1.26	1.11	0.82	0.43	0.47	0.65	0.52	0.43
Algeria	1.40	1.30	0.87	0.10	0.22	0.46	0.65	0.56
Spain	1.45	1.30	0.92		0.18	0.37	0.65	0.52
Belgium	1.59	1.44	1.01	0.18		0.42	0.73	0.65
Norway	1.79	1.59	1.19	0.30	0.18	0.46	0.86	0.82
Trinidad	1.84	1.74	1.29	0.43	0.43	0.28	0.52	0.35
US Gulf via no canals	1.86	1.70	1.49	0.56	0.56		0.78	0.61
US Gulf via Panama canal	1.29	1.53						
US Gulf via Suez canal	2.00	1.79	1.39					

Source: Platts

JKM – NBP and Brent



Arbitrage of JKM and Brent prices

- JKM, NBP and Brent have unit roots; for *diff* = JKM–NBP *p*-value is 0.07
- Regressing *diff* on Brent gives a coefficient of 0.0754 (0.0028) and the residual rejects a unit root with *p*-value 0.0006
- Estimating a VECM using Johansen we find a single cointegrating relationship but D.Brent does not respond to the cointegrating equation error or lagged D.*diff*, only lagged D.Brent
  - Conclude Brent is exogenous to *diff* and
  - There is only a single dynamic equation
- A simple ARIMA model can explain the dynamics of D.*diff*
  - Coefficient on lagged cointegrating equation error = –0.1206 (0.0239)
  - AR(1) = 0.4563 (0.0483), MA(3) = 0.1618 (0.0402)
  - Error is white noise according to Box=Pierce Q-stat

Dynamic model residual