

# Cooperation among LNG exporters: Is rationalization the sole objective?

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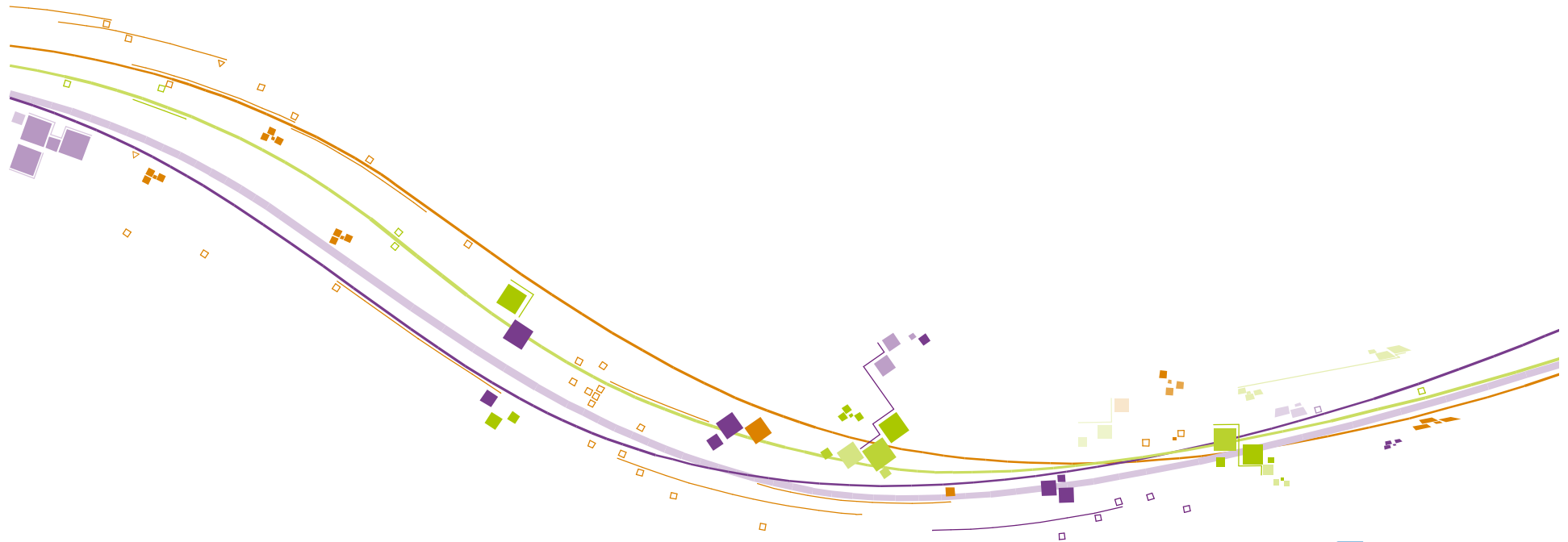


# Outline of talk

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- **I - Some stylized facts on the LNG industry**
  - The GECF: content, objectives
  - Some views on the GECF
  - Research question
  
- **II - Analysis**
  - Modeling the gains derived from a *logistic cooperation*
    - Model formulation
    - Some results
  - A gain sharing approach
    - Can we find a “fair” gain sharing method?
  - A possibly costly coordination: what consequences?
  
- **Summary**

# Some stylized facts





# The GECF

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- **Tehran – 2001: The Gas Exporting Countries Forum (GECF)**
  - **An informal and rather chaotic organization**
    - unstable membership and mandate
    - However, a Liaison Office has recently been established in Qatar
  - **A potentially powerful organization**
    - 79% of world reserves, 56% of world production, 63% of exports (BP, 2008)
    - Seven of these countries are also members of the OPEC

=> Question: **Are we facing an infant GASPEC?**

- **The GECF in the literature**
  - **Mainly policy-oriented papers**
    - Soligo and Jaffe (2004), Hallouche (2006), Wagbara (2007), Finon (2007)...
    - ⇒ An institutional description
    - ⇒ A geopolitical discussion on possible cooperation strategies
  - **Some recent analytical papers**
    - Egging et al. (2009): first large scale model (an MCP formulation)



# Some conventional wisdoms

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## ■ A group of gas or LNG exporters?

### ■ Yergin and Stoppard (2003)

- *"An association of some kind among LNG exporters is likely."*

### ■ J. Stern, CESSA Conference, Cambridge, Dec. 14, 2007

- *"Prime movers are LNG exporters (...) therefore an organization for LNG exporters is more likely than gas exporters"*

## ■ An inoffensive organization?

### ■ J. Stern, CESSA Conference, Cambridge, Dec. 14, 2007

- A gas "price setting" organization/cartel is not an immediate concern

### ■ C. de Margerie (CEO of Total), Interview to Times, Feb. 2007

- *"The cartel of world gas exporters is capable to play a positive role (...). A gas OPEC would help to avoid inefficient investments, that works in interests of the consumers."*

### ■ Mr. Mandil (former Director of the International Energy Agency), Oct. 2008

- *"a think tank for gas exporting countries, enabling them to consider the best possible conditions for the exercise of their mission"*



# Possible research questions

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Question:


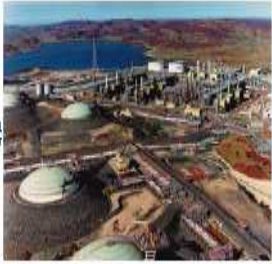


## What is the underlying economic goal?

- Case 1: a cartel that seeks some market power?
  - Cf. Egging et al. (2009)

- Case 2: an inoffensive cooperation of LNG exporters?
  - **QUESTION: IS IT REALISTIC?**



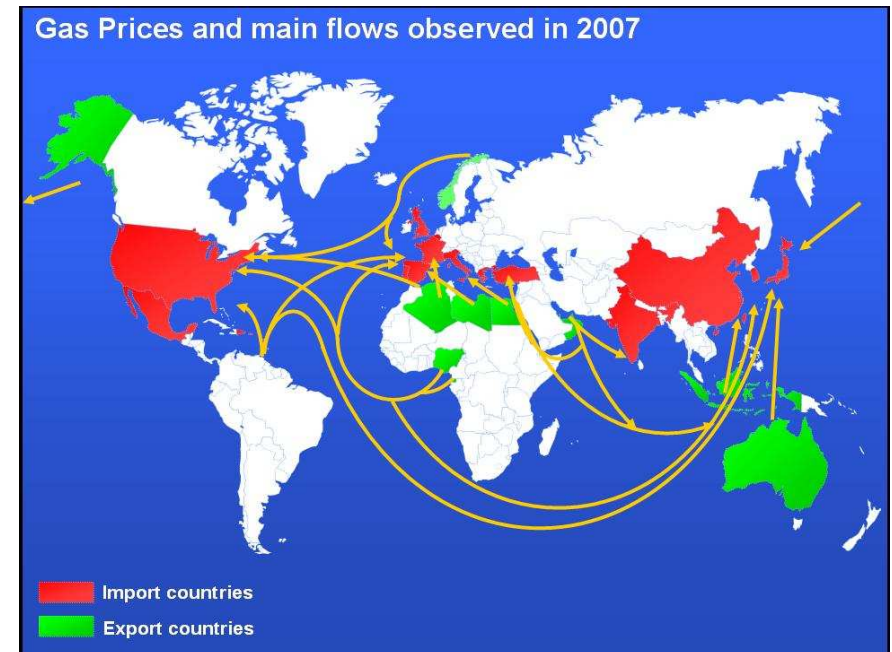
# The LNG Chain in 2007

	 <b>Upstream</b>	 <b>Liquefaction</b>	 <b>Shipping</b>	 <b>Re-gas</b>
<b>Total annual cost (\$ billion)</b>	3.588	7.234	8.167	3.617
<b>%</b>	16.6%	33.4%	33.3%	16.7%

## Shipping:

- Shipping cost is distance dependent
- Observed trade flows are obviously suboptimal
  - Because of bilateral contracts

⇒ The easiest way to organize a cooperation





# Research objectives

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## Questions

1 – How huge would be the collective profit gain derived from a shipping optimization?

2 – Will all GECF countries have an incentive to cooperate?

- If YES, STOP.

- If NO:

- Can we find an adequate rule to share the collective profit gain?
- Can that rule be preferred to "asset swaps" organized outside the GECF?

Suppose now that export coordination is costly,

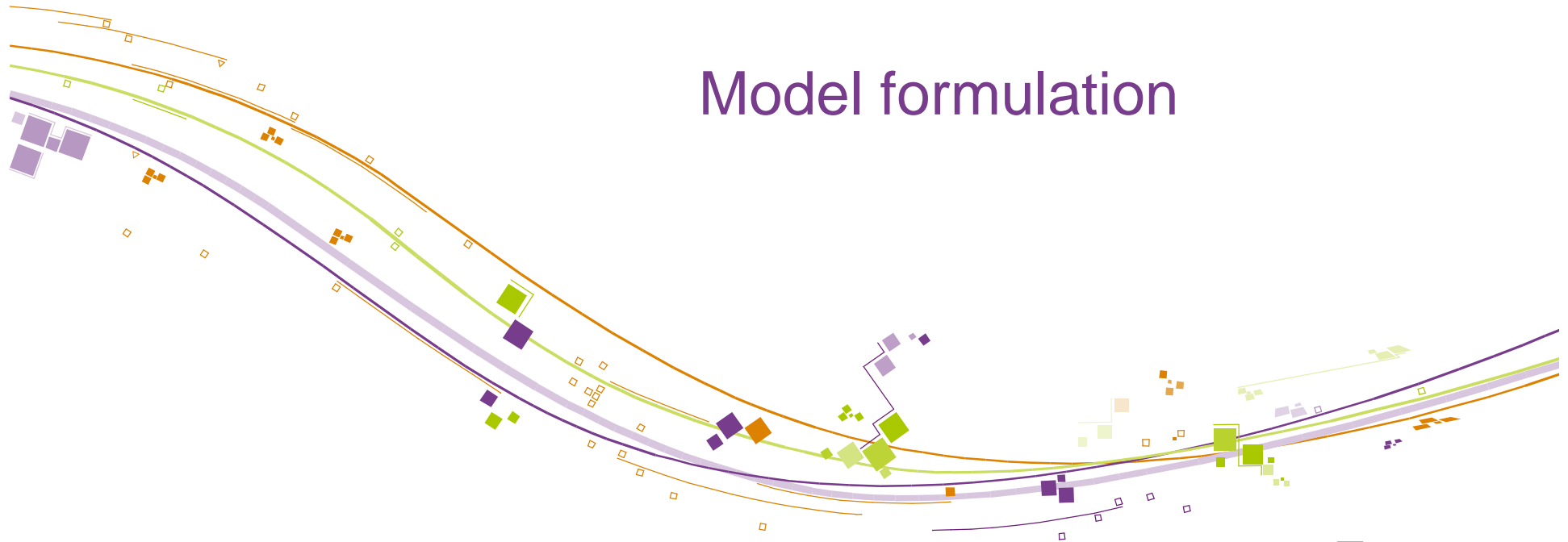
3 – What is the maximum admissible cost of cooperation?

**PROPOSE QUANTITATIVE INSIGHTS  
IN TERMS OF UNDERSTANDING THE GECF**



# Cooperation in LNG trade

Model formulation





# A simple LP model

- Suppose that  $n = 12$  non-OECD LNG exporters decide to cooperate
- Exporter's  $i$  profit as a function of the annual flows  $q_{ij}$ :

$$\pi_i (q_i) = \sum_{j=1}^d (P_j - C_i - T_{ij}) q_{ij}$$

- The GECF objective:

A familiar transportation problem (Dantzig, 1951)

$$\text{Max}_{q_{ij}} \sum_{i=1}^n \pi_i (q_i)$$

$$\text{s.t.} \quad \sum_{j=1}^d q_{ij} = \sum_{j=1}^d Q_{ij} \quad (i = 1, 2, \dots, n)$$

$$\sum_{i=1}^n q_{ij} = \sum_{i=1}^n Q_{ij} \quad (j = 1, 2, \dots, d)$$

$$q_{ij} \geq 0$$

Unchanged utilization rate of liquefaction plants

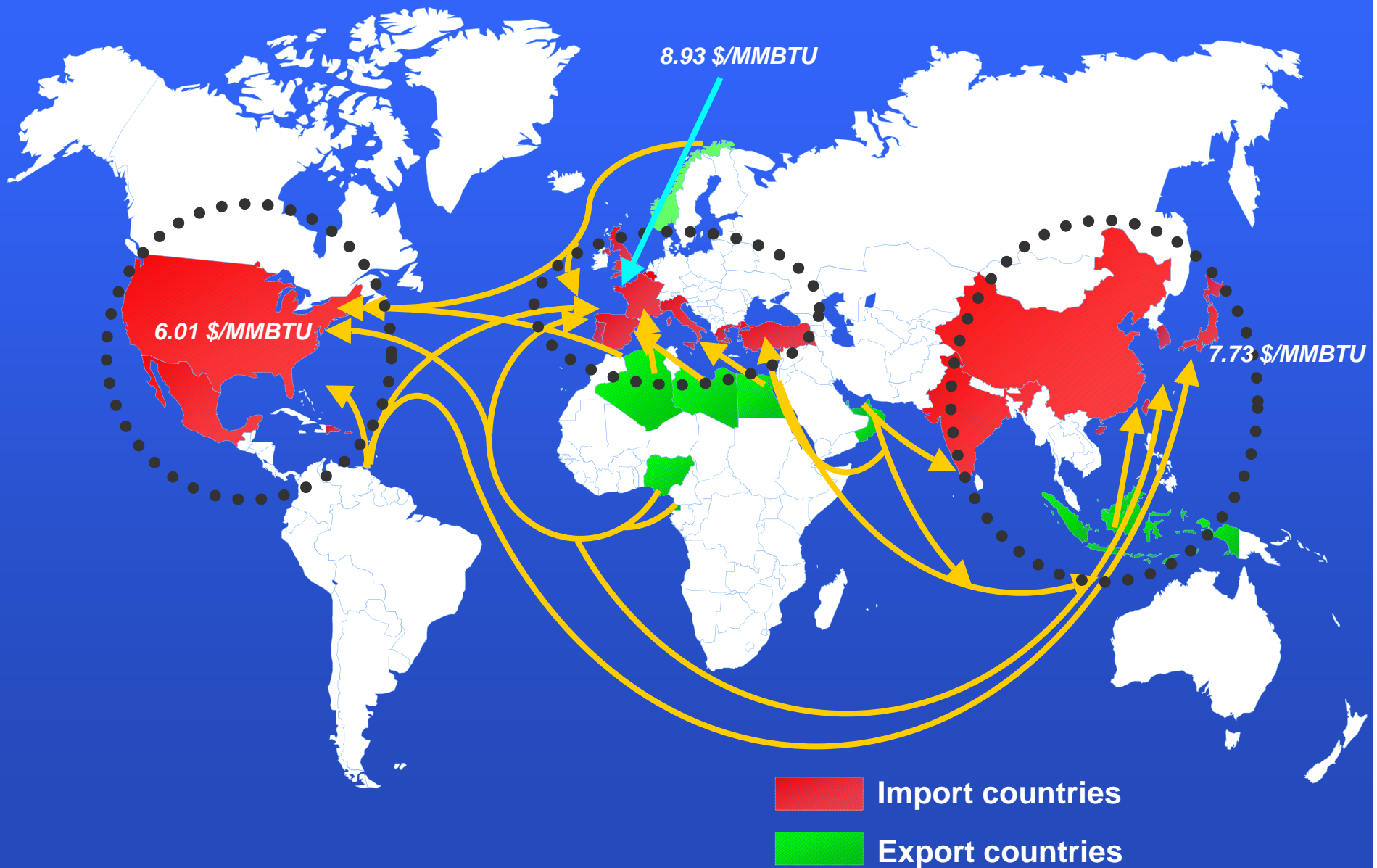
(1)

Unchanged import volumes for each importing country

(2)

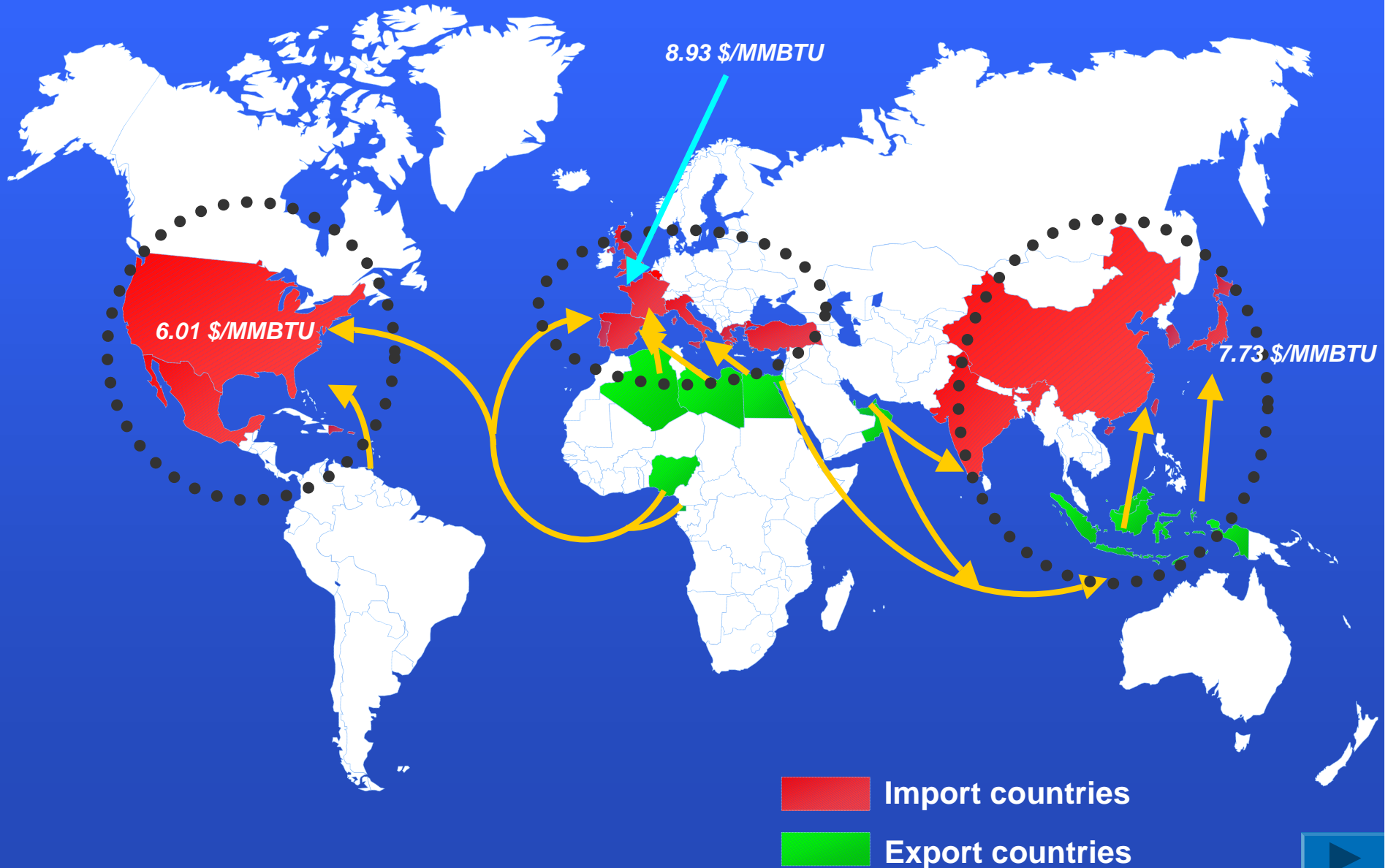
The volume of LNG shipped from  $i$  to  $j$  during the year

# Observed LNG flows in 2007



# Optimized 2007 LNG flows

Collective gain: +M\$ 968  
for 12 countries



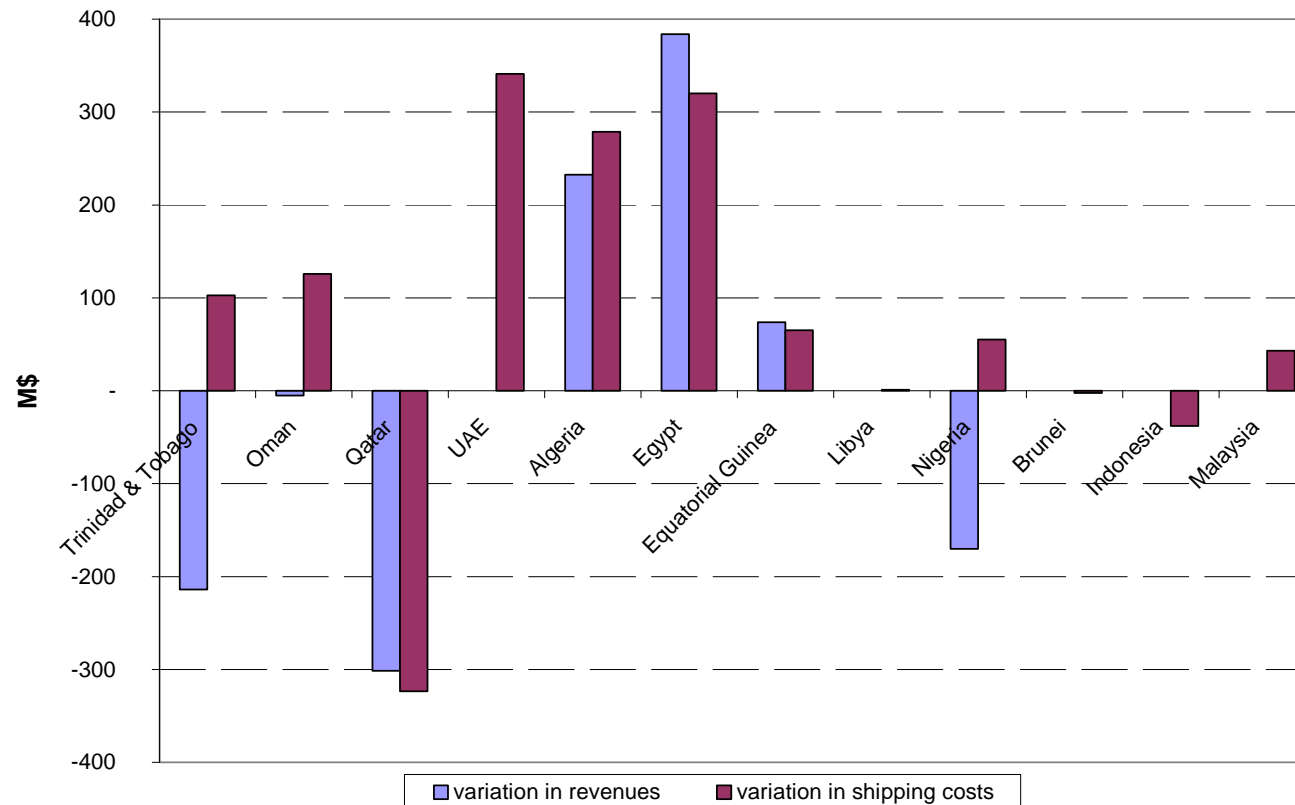


# First Result

=> **RESULT #1: a collectively attractive cooperation**

- An overall collective gain: +M\$ 968 for the 12 countries in 2007
  - an 11.9% reduction in the GECF's shipping cost
  - a +2.8% rise in 2007 profits

■ However....



# Cooperation in the LNG industry

A gain sharing approach





# A TU-game $(N, v)$

**$N$**  - a finite set of  $n$  exporters involved in the GECF

$S \subseteq N$  - a subcoalition of exporters ( $2^{12} = 4096$  coalitions)

$|S|$  - the number of countries in  $S$

**$j$**  - one of these importers

## The characteristic function

- measures, for any coalition  $S$ , the logistic gain that could be obtained thanks to a cooperation

$$v: 2^N \rightarrow \mathbf{R}$$

$$S \mapsto v(S) = \text{Max}_{q_{ij}} \sum_{i=1}^n \delta_i(S) \cdot (\pi_i(q_i) - \pi_i(Q_i))$$

$$\text{s.t.} \quad \sum_{j=1}^d q_{ij} = \sum_{j=1}^d Q_{ij} \quad (i = 1, 2, \dots, n)$$

$$\sum_{i=1}^n q_{ij} = \sum_{i=1}^n Q_{ij} \quad (j = 1, 2, \dots, d)$$

$$(1 - \delta_i(S)) q_{ij} = Q_{ij} \quad ((i, j) \in \{1, 2, \dots, n\} \times \{1, 2, \dots, s\})$$

$$q_{ij} \geq 0$$



# Some natural requirements

- An « acceptable » gain allocation rule  $\mathbf{x}=(x_i)_{i \in N}$  satisfies:

- Efficiency

$$\sum_{i=1}^n x_i = v(N)$$

- Individual rationality:

for each  $i$   $x_i \geq v(\{i\})$

- Coalitional rationality:

for each  $S \subseteq N$   $\sum_{i \in S} x_i \geq v(S)$

**Thus,**

**$\mathbf{x}$  must belong to the CORE of the game!**





# From basic sharing rules...

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- **There exists a multitude of possible sharing rules**
  - **Trivial examples include**
    - **Equal shares**
      - 1/12 for each country
    - **Proportional to profit earned in 2007**
      - Profits variations: +2.78 % for each exporter
    - **Proportional to total quantity shipped in 2007**
  - **A method inspired by cost sharing methods (Ransmeier, 1932)**
    - **Each country  $i$  receives**
      - its marginal value contribution :  $m_i = v(N) - v(N \setminus \{i\})$
      - corrected so as to recover exactly  $v(N)$

$$x_i = m_i - \left( \sum_{i=1}^n m_i - v(N) \right) \frac{m_i - v(\{i\})}{\sum_{p=1}^n (m_p - v(\{p\}))}, \quad \forall \{i\} \in N$$



## ... to more advanced sharing rules

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- Shapley Value

- Nucleolus-inspired methods

- The Nucleolus (Schmeidler, 1969)

- The "*unhappiness*" of coalition  $S$  with the proposed allocation is:

$$e(S, x) = v(S) - \sum_{\{i\} \in S} x_i$$

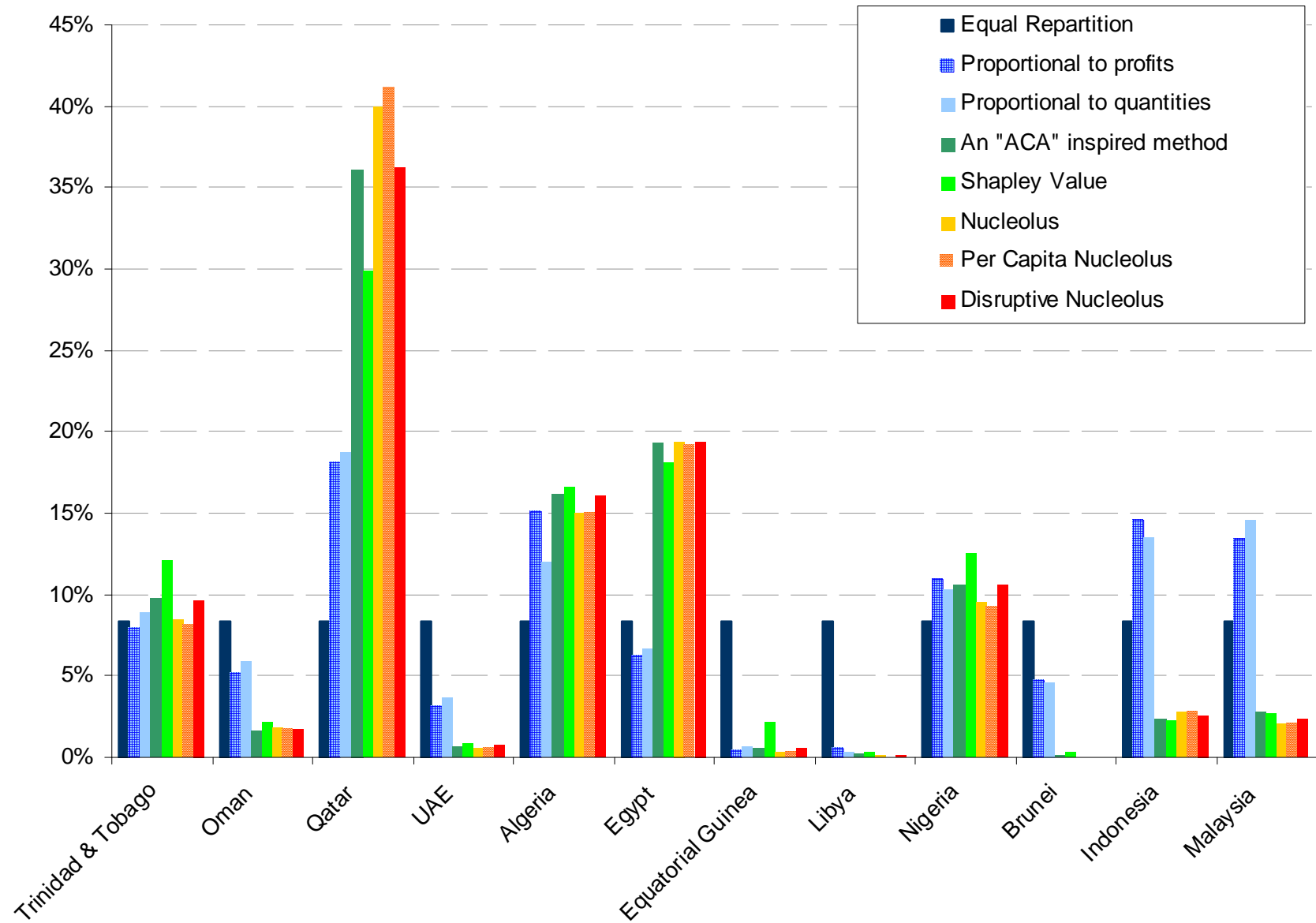
- The nucleolus is the imputation that maximizes (lexicographically) the satisfaction obtained by the least well-off coalition.

- The Per Capita Nucleolus (Grotte, 1970)

- The Disruption Nucleolus (Gately, 1974; Littlechild & Vaidya, 1976)



# Results





# But are they in the CORE?

	Equal shares	Proportional to profit	Proportional to quantities	ACA	Shapley Value	Nucleolus	Per Capita Nucleolus	Disruptive Nucleolus
Does it belong to the CORE ?	No	No	No	No	No	YES	YES	YES
Number of coalitions that could quit the grand coalition ?	981	756	748	2	52	0	0	0

**=> RESULT #2: Selecting an allocation within the core is not so easy**

- Only 3 nucleolus-inspired methods satisfy this minimal requirement
  - No individual earns less than in a stand alone case
  - No coalition of exporters earn less than in a stand alone asset swap



# Another Desirable Requirement

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## ■ Monotonicity in the aggregate

- After participants commit to an allocation, then
  - No participant would receive more if the profit were to decrease
  - No participant would receive less if the profit were to increase
- A "fair" requirement...

=> **RESULT #3: Core & Monotonicity => a restricted choice**

Only one method remains: **the per capita nucleolus**

THUS,  
IDENTIFYING AN ADMISSIBLE  
SHARING METHOD IS NOT SO SIMPLE!

# Cooperation in the LNG industry

What about a costly coordination?





# Coordination Cost

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- Now, let's assume that all the 12 countries agree to use the per capita nucleolus as a profit sharing scheme.
- Suppose that a coordination cost is needed
  - e.g. to cover the cost of a General Secretariat

- **QUESTION:**

**What is the maximum sustainable coordination cost for such a cooperation ?**

- Thanks to this framework, we are able to compute the maximum « allowable » cost of coordination.
  - those compatible with a non-empty core

- Answer: **\$720,000**

- Above that figure, the « market power free » cooperation can no longer be sustained

# Cooperation in the LNG industry

## CONCLUSIONS







# Summary

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1. A « market power free » coordination could provide a collective profit gain.
2. But countries will not spontaneously cooperate  
=> a profit sharing rule is needed
3. Sharing these gains requires advanced cooperative game theory concepts  
Not easy to negotiate...
3. The incentive to cooperate might not be so strong
4. Especially if the coordination costs are reasonable but significant

**MAIN CONCLUSION:  
IS THE "NO MARKET POWER" HYPOTHESIS  
REALLY CREDIBLE?**



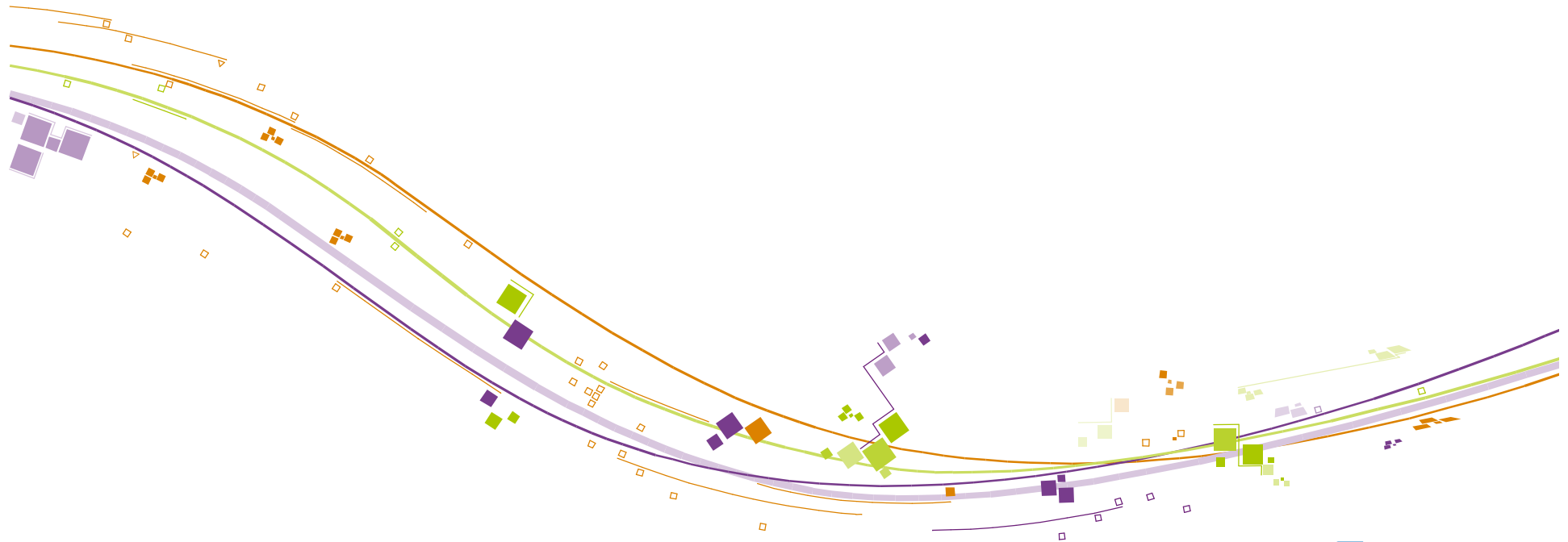
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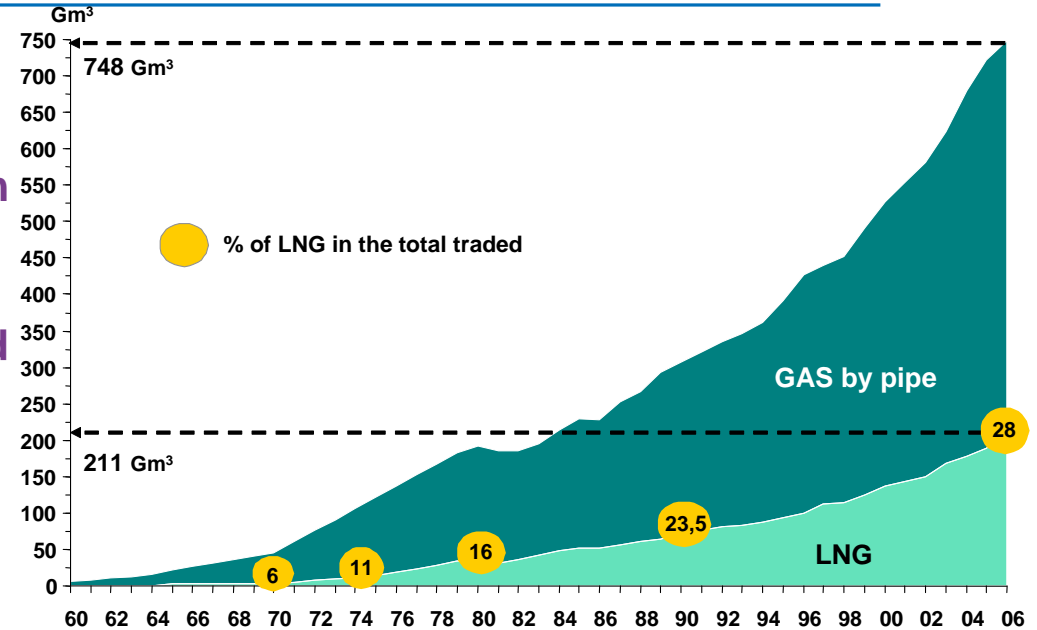


# Back Up



# LNG in 2007

- **The LNG trade in 2007:**
  - 171 Million Tons of LNG ~ 230 Bcm
  - ~ 8% of the worldwide gas consumption
  - ~ 2,800 standard cargoes delivered
  - 15 exporting countries
  - 17 importing countries



Source : BP Statistical Review

- **LNG growth is 5 times higher than gas consumption growth**
- **Fundamental changes reshape the LNG scene**
  - More importing countries (China, India, South America etc...)
  - More LNG sold in liquid gas markets
  - More “flexible LNG”



# Some cost hypothesis

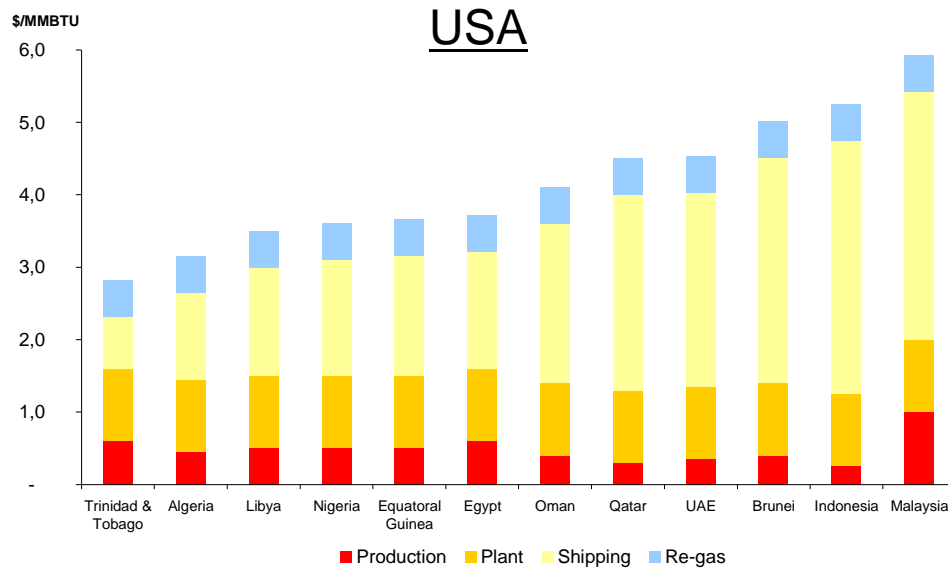
## ■ Production & Liquefaction costs:

	Extraction Cost \$/MMBTU	Liquefaction Cost \$/MMBTU	$L_i$ \$/MMBTU
Trinidad & Tobago	0,60	1,00	1,60
Oman	0,40	1,00	1,40
Qatar	0,30	1,00	1,30
UAE	0,35	1,00	1,35
Algeria	0,45	1,00	1,45
Egypt	0,60	1,00	1,60
Equatorial Guinea	0,50	1,00	1,50
Libya	0,50	1,00	1,50
Nigeria	0,50	1,00	1,50
Brunei	0,40	1,00	1,40
Indonesia	0,25	1,00	1,25
Malaysia	1,00	1,00	2,00

- Regas cost: 0.50 \$/MMBTU
- FLOOD (1954):  $T_{ij}$  unit transmission cost between  $i$  and  $j$ 
  - Standard LNG carriers
    - Capacity, speed, un/loading time...

# LNG Supply Economics

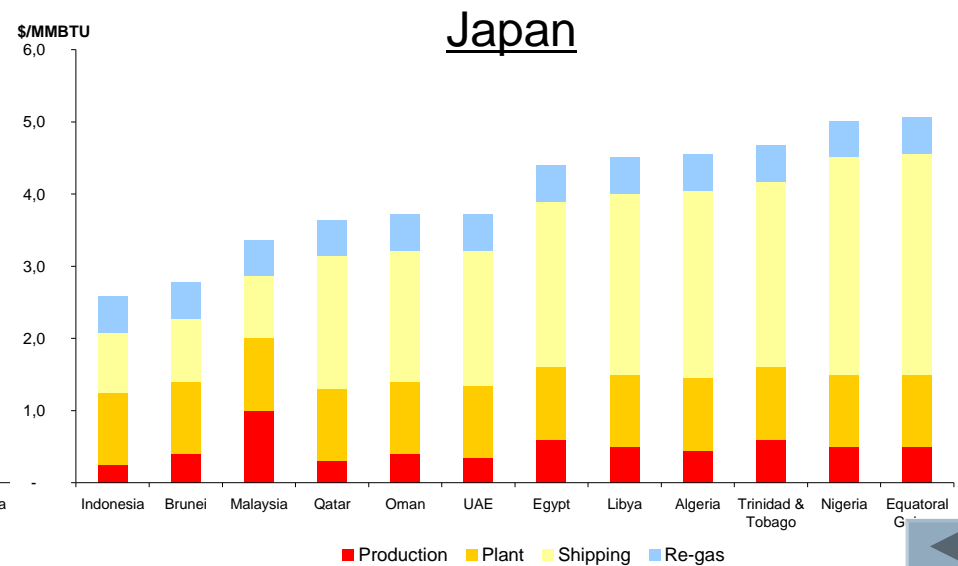
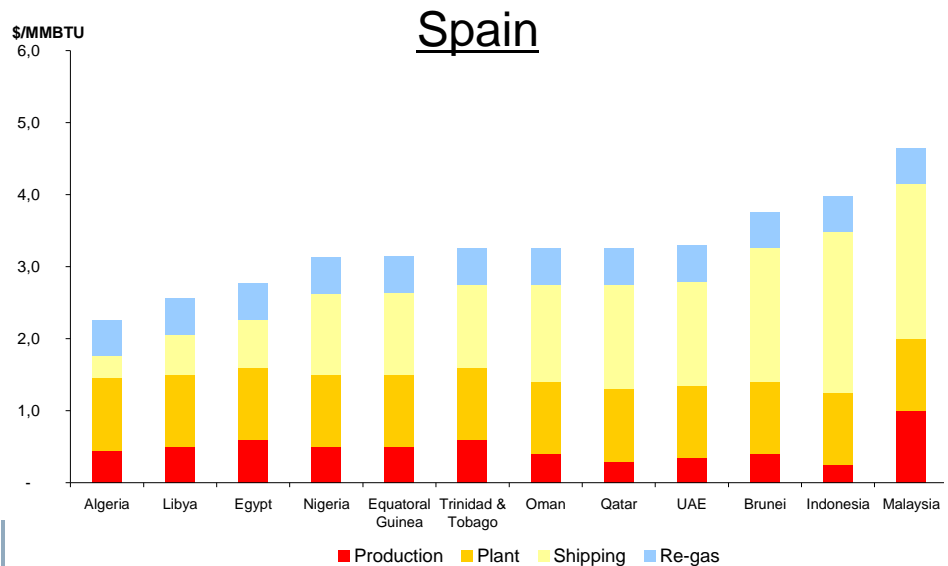
## Insights from a merit-order



There are important cost differences!

A combination of

- geological endowment (Extraction costs differences)
- Localization of liquefaction and reception plants





# The LNG Value Chain

		<b>Billion USD</b>	<b>%</b>
<b>E&amp;P cost</b>	<b>Production</b>	<b>3.588</b>	<b>16.6%</b>
<b>LNG cost</b>	<b>Plant</b>	<b>7.234</b>	<b>33.4%</b>
	<b>Shipping</b>	<b>8.167</b>	<b>33.3%</b>
	<b>Re-gas</b>	<b>3.617</b>	<b>16.7%</b>
<b>Total cost</b>		<b>21.638</b>	<b>100.0%</b>
<b>Rent</b>		<b>34.870</b>	
<b>TOTAL revenue</b>		<b>57.476</b>	





# Some observations on the gain

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- **v is superadditive**

$$\text{2 coalitions } \mathbf{A, B}, \quad A \cap B = \emptyset \quad v(A \cup B) \geq v(A) + v(B)$$

***=> It always pays to enlarge the size of the cooperation***



# Some observations on the gain

- The Marginal value scheme is not efficient

$$m_i = v(N) - v(N \setminus \{i\})$$

Marginal contribution of each GECF country (k\$)

	marginal contribution of i
Trinidad & Tobago	123.695
Oman	20.253
Qatar	459.779
UAE	8.386
Algeria	205.191
Egypt	245.722
Equatorial Guinea	6.663
Libya	2.149
Nigeria	134.774
Brunei	0.721
Indonesia	30.113
Malaysia	34.99
TOTAL	1272.43



**=> There are significant differences among countries**