The 36th USAEE/IAEE North American Conference
Hilton Crystal City Hotel, Washington, D.C.
23 – 26 September 2018

Competition and Cooperation in the Natural Gas Market

Youngho Chang

School of Business
Singapore University of Social Sciences

24 September 2018

Agenda

- Introduction
  - World gas market outlook
  - Qatar in European pipeline natural gas (PNG) market
  - Russia in Asia-Pacific liquefied natural gas (LNG) market
- Gas pricing models
  - Statistical approaches
  - Linear/Non-linear programming techniques
  - Game theoretic models
- The Analytical Framework
  - Russia for Asia-Pacific via LNG
  - Qatar for European via pipe
- Analyses and Discussions
  - Estimation of demand curves
  - Results
  - Sensitivity analyses
- Concluding Remarks

Introduction

Literature Review

The Analytical Framework

Analyses and Discussions

Conclusion

World gas market

- The development of global and regional gas trade has been a story of rocketing growth, diversification and increased flexibility in infrastructure planning.

- US shale gas affected the world market.

- A shale gas boom in other parts of the world remains unlikely in the middle to long term (Boersma, 2013).

- The gas outlook in the rest of the world, hence, depends largely on the gas supply and demand of major international players: the exporters (Russia and Qatar) and the importers (Asia-Pacific and Europe).

Qatar in European PNG market

- The practice of transporting Russian pipeline natural gas (PNG) to Europe via transit countries has been plagued by recurring problems, e.g., gas disputes with Ukraine and Belarus in 2006 and 2009

- Europe imported 423.4 billion cubic meters (bcm) of PNG, about 57% of the world imports (BP, 2018)
  - 189.3 bcm from Russia, about 45% of the total PNG imports
  - No PNG exports from Russia to Asia-Pacific

- As it becomes Europe's interests to seek alternative gas supply sources (Ratner et al., 2013), potential suppliers such as Qatar can enter to gain a foothold in the European pipeline gas market.

Russia in Asia-Pacific LNG market

- Facing with such a situation, Russia too increasingly embraces a strategic position by diversifying from PNG exports to liquefied natural gas (LNG) production on the Yamal Peninsula (Kardas, 2013), targeting the Asia-Pacific market.

- LNG imports by Asia-Pacific have grown from 227.2 billion cubic meters (bcm) in 2012 (BP, 2013) to 283.5 bcm in 2017 (BP, 2018) – about 72% of global share.
  - Asia-Pacific imported 15.4 bcm of LNG from Russia in 2017

- General consensus agrees that the growing Asia-Pacific LNG demand facilitates the probable entry of Russia as a supply competitor to Qatar.

Introduction

Literature Review

The Analytical Framework

Analyses and Discussions

Conclusion

Statistical Approach

- Study correlations between key commodities prices and shows inter-regional price convergence by econometric time series data or arithmetic Kalman-Filter method.

Methods	Studies	Key findings
Econometric	Brown and Yucel, 2009	Price integration across isolated regional markets exists, with LNG as the critical factor, not oil price.
Kalman-Filter	Neumann, 2009	Increasingly converging spot prices across Atlantic.

Linear/Non-linear Programing 1

- Contains a collection of sophisticated models under a dynamic network setting.

- The World Gas Trade Model presents a pattern of transporting routes and prices that minimize producers' rents with a competitive framework (Hartley and Medlock III, 2009).

- The perfectly competitive European gas market structure of the World Gas Trade Model is different from the oligopolistic market in a game theoretical framework of GASMOD (see Holz et al., 2009) and the static version of the GASTALE model (see Boots et al., 2004).

Linear/Non-linear Programing 2

Linear/ Non-linear programming	Aune et al., 2008 (FRISBEE model)	Inter-continental trade projected to grow in the medium term, prices in main import regions to be stable at current levels.
	Netsbitt and Scotcher, 2009 (Spatial commodity)	Price effects in a spatial network are transmitted through the spatial system of inter-connected supply and demand.
	Lise and Hobbs, 2009 (GASTALE model)	Prices are attributed to interactions of the supplier's ability to exercise market power and the accessibility of the market.
	Egging et al., 2009 (World gas model)	A global gas cartel reduces gas supplied and increases gas prices by up to 22%.
	Hartley and Medlock III, 2009 (RICE World gas trade)	In the long term, Russia's influence of the global market is constrained due to competition.
	Holz et al., 2009 (GASMOD model)	In the future, Russia does not dominate in the European market, Middle East continues to be a modest gas supplier, and Europe is more dependent on LNG imports.
	Zwart, 2008 (NATGAS model)	Reducing current prices, which results in higher future prices, can increase welfare.
	Lochner and Dieckhöner, 2010 (TIGER model)	European gas market in the next decade is generally well integrated physically.

Game Theoretical Models 1

- The impact of the entry of LNG producers on competitively-priced gas is studied (see Dorigoni et al., 2009).

- Interactions between a pipeline gas exporter and transit countries are also addressed (see Chernavsky and Eistmont, 2012; von Hirschhausen et al., 2005).

Game Theoretical Models 2

Game Theoretical	von Hirschhausen et al., 2005	Putting Belarus as an alternative transit country to Ukraine, Russia's profit increases significantly.
	Dorigoni et al., 2009	LNG importers have a positive impact on competition under an active spot market.
	Chernavsky and Eistmont, 2012	Russia can increase profit by setting price of gas for Ukraine as a function of Ukraine's transit tariff.

Introduction

Literature Review

The Analytical Framework

Analyses and Discussions

Conclusion

Russia for Asia-Pacific via LNG:

Nomenclature

P_l	Price of Asia-Pacific LNG (assume oil-delinking)
Q_l	Volume of LNG demanded from Asia-Pacific
Q_{li}	Volume of LNG exported from country i
l_i	Unit liquefaction cost in export country i
c_i^e	Gas unit extraction cost in export country i
m_i	Miscellaneous unit exporting cost in export country i
Q_X	LNG export volume from exporters
P_X	LNG export price charged by exporters
Q_M	LNG import volume by importers
P_M	LNG import price paid by importers

Russia for Asia-Pacific via LNG: Three Stages

- Stage 1: Stackelberg Game
- Stage 2: Cournot Game
- Stage 3: Bilateral Monopoly
  - Monopoly (exporters) and Monopsony (importers)

Russia for Asia-Pacific via LNG

- Assume the residual inverse demand for LNG in Asia-Pacific up to 2020, served by Qatar and Russia, is:

$$P_l = a_l - b_l Q_l$$

where a_l and b_l are the parameters

- Marginal cost of exporting gas of country i is:

$$MC_{li} = m_i + \left(l_i + c_i^e\right) Q_{li}$$

- The game between Russia and Qatar is determined by the LNG export capacity of Russia, which in turn relies on the commissioning of some gas fields such as Shtokmanovskoye, Vladivostok, and Yamal in Russia.

Russia for Asia-Pacific via LNG

Stage 1: Stackelberg game 1

- The inverse demand function supplied by Russia and Qatar is:

$$P_l = a_l - b_l\left(Q_{lR} + Q_{lQ}\right)$$

- Profit function of Russia, the follower, is:

$$\pi_{lR} = P_l Q_{lR} - \int_0^{Q_{lR}} MC_{lR}\, dQ_{lR} = \left[a_l - b_l\left(Q_{lR} + Q_{lQ}\right)\right]Q_{lR} - m_R Q_{lR} - \left(l_R + c_R^e\right)\frac{Q_{lR}^2}{2}$$

- Optimal exporting volume for Russia is:

$$Q_{lR}^{*S} = \frac{a_l - b_l Q_{lQ}^{S} - m_R}{2b_l + l_R + c_R^e}$$

Russia for Asia-Pacific via LNG

Stage 1: Stackelberg game 2

- Profit function of Qatar, the leader, is:

$$\pi_{lQ} = P_l Q_{lQ} - \int_0^{Q_{lQ}} MC_{lQ} dQ_{lQ} = \left[a_l - b_l\left(Q_{lQ} + Q_{lR}\right)\right]Q_{lQ} - m_Q Q_{lQ} - \left(l_Q + c_Q^e\right)\frac{Q_{lQ}^2}{2}$$

- Optimal exporting volume for Qatar is:

$$\pi_{lQ} = \left[a_l - b_l\left(Q_{lQ} + \frac{a_l - b_l Q_{lQ} - m_R}{2b_l + l_R + c_R^e}\right)\right]Q_{lQ} - m_Q Q_{lQ} - (l_Q + c_Q^e)\frac{Q_{lQ}^2}{2}$$

- Optimal exporting volume for Qatar is:

$$Q_{lQ}^{*S} = \frac{\left(a_l - m_Q\right)\left(2b_l + l_R + c_R^e\right) - b_l\left(a_l - m_R\right)}{\left(2b_l + l_R + c_R^e\right)\left(2b_l + l_Q + c_Q^e\right) - 2b_l^2}$$

Russia for Asia-Pacific via LNG

Stage 2: Cournot game

- In the medium run, when Russia's LNG production ramps up, Russia acquires a larger share of the Asia-Pacific market; the Stackelberg game becomes the Cournot game.

- The best response function for Russia is:

$$Q_{lR}^{*C} = \frac{(a_l - m_R)(2b_l + l_Q + c_Q^e) - b_l(a_l - m_Q)}{(2b_l + l_R + c_R^e)(2b_l + l_Q + c_Q^e) - b_l^2}$$

- Optimal exporting volume for Qatar is:

$$Q_{lQ}^{*C} = \frac{(a_l - m_Q)(2b_l + l_R + c_R^e) - b_l(a_l - m_R)}{(2b_l + l_R + c_R^e)(2b_l + l_Q + c_Q^e) - b_l^2}$$

Russia for Asia-Pacific via LNG

Stage 3: Bilateral monopoly game 1

- If Russia and Qatar collude to form a monopoly exporter, Asia-Pacific importers are presumed to unite and become a monopsony buyer.

- For exporters: The total marginal cost (supply curve) is the horizontal summation of members' marginal costs.

$$P_l = MC_l = \frac{Q_l + \left(\frac{m_R}{l_R + c_R^e} + \frac{m_Q}{l_Q + c_Q^e} \right)}{\frac{1}{l_R + c_R^e} + \frac{1}{l_Q + c_Q^e}}$$

- Optimal exporting volume is when: $MC_l = MR_l$

$$Q_X^* = \frac{(a_l - m_R)(l_Q + c_Q^e) + (a_l - m_Q)(l_R + c_R^e)}{(l_Q + c_Q^e)(l_R + c_R^e) + 2b(l_Q + c_Q^e + l_R + c_R^e)}$$

Russia for Asia-Pacific via LNG

Stage 3: Bilateral monopoly game 2

- For importers: The marginal revenue product curve from importing LNG: $P_l = MRP$

- Marginal factor cost of importing LNG is:

$$MFC_l = \frac{dTC_l}{dQ_l} = \frac{2Q_l + \left(\frac{m_R}{l_R + c_R^e} + \frac{m_Q}{l_Q + c_Q^e} \right)}{\frac{1}{l_R + c_R^e} + \frac{1}{l_Q + c_Q^e}}$$

- Optimal importing volume is when: $MFC_l = P_l$

$$Q_M^* = \frac{(a_l - m_R)(l_Q + c_Q^e) + (a_l - m_Q)(l_R + c_R^e)}{2(l_Q + c_Q^e)(l_R + c_R^e) + b(l_Q + c_Q^e + l_R + c_R^e)}$$

Qatar for Europe via gas pipeline:
Nomenclature

P_{QE}	PNG export price that Qatar charged to Europe
Q_{QE}	PNG export volume from Qatar to Europe
P_E	PNG price that European actually pays
Q_E	European PNG volume demanded that is met by Qatar
P_{Qk}	PNG export price that Qatar charged to transit country k ($k=t$ for Turkey)
Q_{Qk}	PNG export volume that Qatar exported to transit k
P_k	PNG price that transit country k actually pays
Q_k	PNG volume demanded from transit country k
q_k	PNG own production of transit country k
c_Q	PNG unit cost of production and transportation incurred by Qatar
c_{kT}	Unit cost of transporting gas incurred by transit country k
τ_k	Transit fee charged by transit country k per unit of gas volume

Qatar for Europe via gas pipeline

- Figure A.1 presents a proposed hypothetical gas pipeline where the route designed would take Turkey as the last transit country before the gas arrives at other countries in Europe.
- It is assumed that the domestic production of a transit country is much smaller than the total gas demand of the transit country, or $q_k << Q_k(P_k)$, so that Qatar has some market power in these transit countries

FIGURE A.1: PROPOSED PNG ROUTE FROM QATAR TO TURKEY

Qatar for Europe via gas pipeline Three cases

- Qatar transports gas up to the European border
- Qatar sells all the gas to Turkey
- Qatar applies discriminating pricing schemes to Europe and Turkey

- Adopted from Chernavsky and Eistmont (2012)

Qatar for Europe via gas pipeline

Case 1: Qatar transports gas up to the European border 1

- Assume linear demand curve for Europe and transit countries

- Qatar's profit is expressed as follows:

$$\pi_Q = \left(P_{QE} - c_Q - \sum_{k=1}^{n} \tau_k \right) Q_{QE}\left(P_{QE}\right) + \sum_{k=1}^{n} \left(P_{Qk} - c_Q\right)\left[Q_{Qk}\left(P_{Qk}\right) - q_k\right]$$

- For a transit country, the profit from transportation of European gas is given by:

$$\pi_k = \left(\tau_k - c_{kT}\right) Q_{QE}\left[P_{QE}^{*}\left(\tau_1, \tau_2, \ldots, \tau_n\right)\right]$$

Qatar for Europe via gas pipeline

Case 1: Qatar transports gas up to the European border 2

- The price that Qatar charges Europe is:

$$P_{QE}^{*} = \frac{1}{4}\left[\frac{a_E}{b_E}(2+n) + c_Q(2-n) + \sum_{k=1}^{n} c_{kT} - (n-1)\sum_{k=1}^{n}\tau_k\right]$$

- The optimal transit fee is:

$$\tau_k^{*} = \frac{1}{2}\left(\frac{a_E}{b_E} - c_Q + c_{kT} - \sum_{k \neq j}\tau_j\right)$$

- The optimal price that Qatar charges to transit countries and the optimal volumes sold are:

$$P_{Qk}^{*} = \frac{a_k - q_k + b_k c_Q}{2b_k} \qquad Q_{Qk}^{*} = \frac{1}{2}\left(a_k + q_k - b_k c_Q\right)$$

Qatar for Europe via gas pipeline

Case 2: Qatar sells all the gas to Turkey

- Turkey's profit function is:

$$\pi_t = (P_E - P_{Qt} - c_{tT})Q_E(P_E)$$

- Qatar's profit from exporting gas to Turkey is:

$$\pi_Q = (P_{Qt} - c_Q)\{Q_E[P_E(P_{Qt})] + Q_{Qt}(P_{Qt}) - q_t\}$$

- The profit-maximizing volume that Qatar should sell to Turkey is given by:

$$P_{Qt}^* = \frac{a_E + 2a_t - 2q_t + (c_Q - c_{tT})b_E + 2c_Q b_t}{2(b_E + 2b_t)}$$

- The optimal price charged to Europe is

$$P_E^* = \frac{\frac{3}{2}a_E b_E + \frac{1}{2}(c_Q + c_{tT})b_E^2 + b_E b_t(c_Q + c_{tT}) + b_E(a_t - q_t) + 2a_E b_t}{2b_E(b_E + 2b_t)}$$

Qatar for Europe via gas pipeline

Case 3: Qatar applies discriminating pricing schemes to Europe and Turkey 1

- It is assumed that the gas price paid by European countries is $P_E = P_{QE} + \tau_t$ where τ_t is the transportation tariff charged by Turkey.

- Qatar's profit from exporting gas to Turkey is:

$$\pi_Q = \left(P_{QE} - c_Q\right) Q_{QE}\left(P_{QE} + \tau_t\right) + \left(P_t - c_Q\right)\left[Q_{Qt}\left(P_{Qt}\right) - q_t\right]$$

- Turkey's profit from transporting Qatari gas to Europe is:

$$\pi_t = \left(\tau_t - c_{tT}\right) Q_{QE}\left(P_{QE} + \tau_t\right)$$

- The optimal transportation tariff is:

$$\tau_t^*\left(P_{QE}\right) = \frac{1}{2}\left(\frac{a_E}{b_E} - P_{QE} + c_{tT}\right)$$

Qatar for Europe via gas pipeline

Case 3: Qatar applies discriminating pricing schemes to Europe and Turkey 2

- The optimal price that Qatar should charge Europe is:

$$P_{QE}^{*} = \frac{1}{2}\left(\frac{a_E}{b_E} + c_Q - c_{tT}\right)$$

- The optimal transit fee is:

$$\tau_t^{*} = \frac{1}{4}\left(\frac{a_E}{b_E} - c_Q + 3c_{tT}\right)$$

- The optimal price that Europe pays is:

$$P_E^{*} = \frac{1}{4}\left(3\frac{a_E}{b_E} + c_Q + c_{tT}\right)$$

- The optimal price that Qatar charge to Turkey is:

$$P_{Qt}^{*} = \frac{1}{2}\left(\frac{a_t}{b_t} + c_Q - q_t\right)$$

Introduction

Literature Review

The Analytical Framework

Analyses and Discussions

Conclusion

Estimation of Demand Curves

- The Asia-Pacific residual demand curve for Qatar and Russia is established from two data points: one data point from 2012 and the other from 2020 estimates (when LNG price is assumed to be delinked from oil).
- Projections for European gas pipeline import demand curve served by Qatar employ two data points: 2020 and 2025 when the gas pipeline is built.

Russia for Asia-Pacific via LNG Results 1

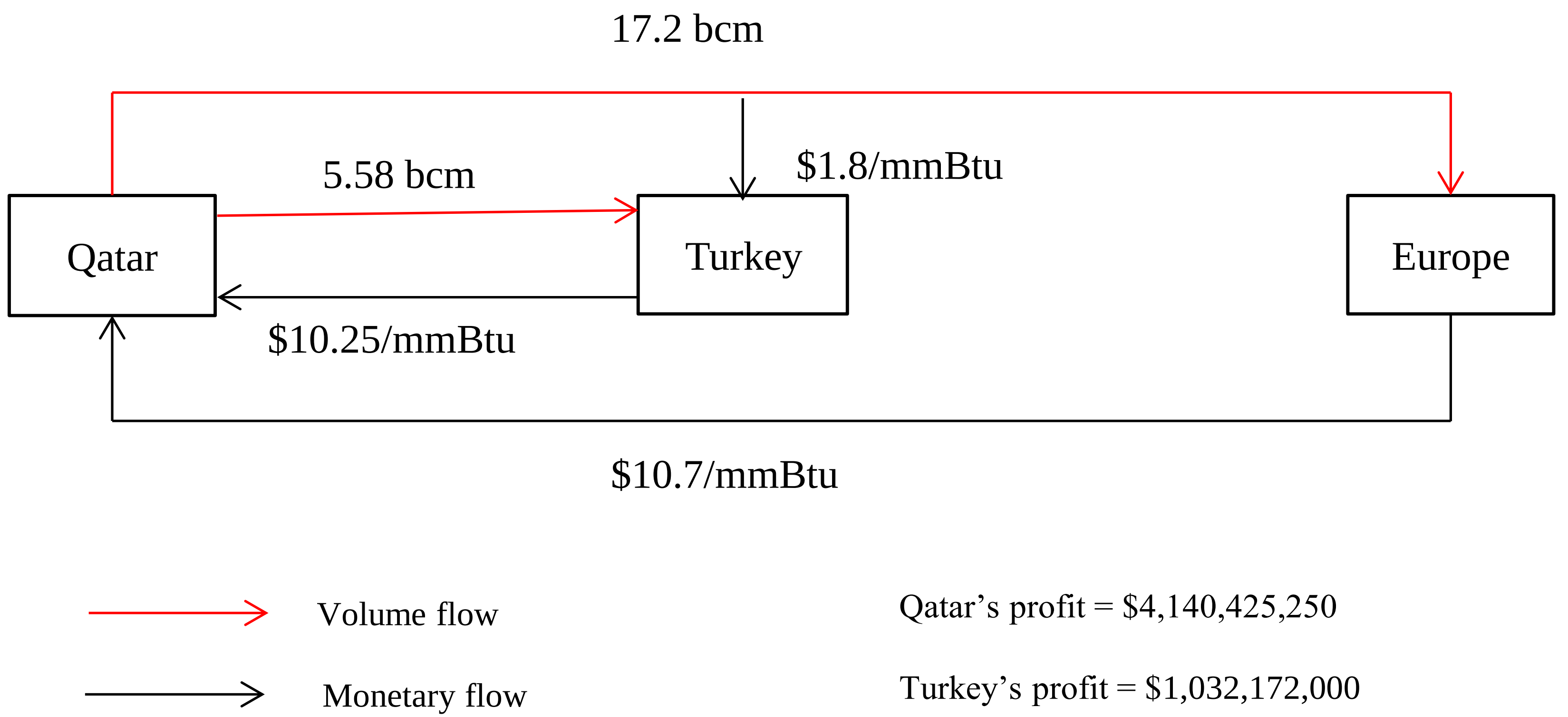
	Stage 1	Stage 2	Stage 3
Price ($/mmBtu)	9.46	10.02	-
Russia's volume (bcm)	50.39	53.49	-
Qatar's volume (bcm)	137.99	123.97	-
Russia's profit ($)	10,466,468,182	11,796,892,359	-
Qatar's profit ($)	34,149,030,787	38,173,269,460	-
Export price ($/mmBtu)	-	-	11.42
Export volume (bcm)	-	-	150.52
Import price ($/mmBtu)	-	-	4.67
Import volume (bcm)	-	-	208.22

Russia for Asia-Pacific Results 2

- The Cournot stage yields higher profits for both Russia and Qatar than the Stackelberg stage.

- In the Bilateral Monopoly stage, an optimal import price is lower than an optimal export price because importers (e.g., the Monopsony or Asia-Pacific countries) always want to bargain for lower price than what is considered optimal for exporters.

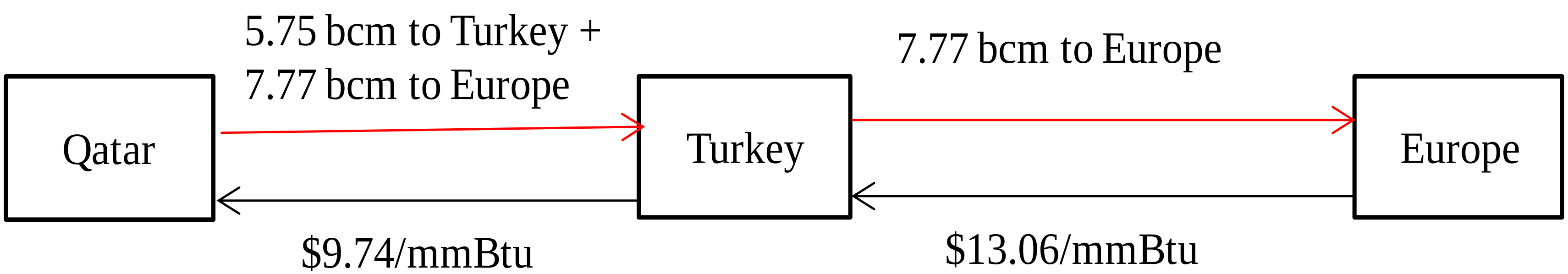
Qatar for Europe via gas pipeline Case 1 Results

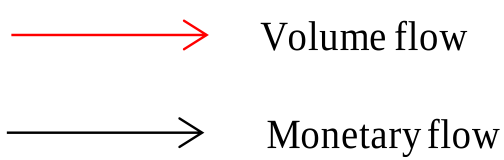


Qatar's profit = $4,140,425,250

Turkey's profit = $1,032,172,000

Qatar for Europe via gas pipeline Case 2 Results

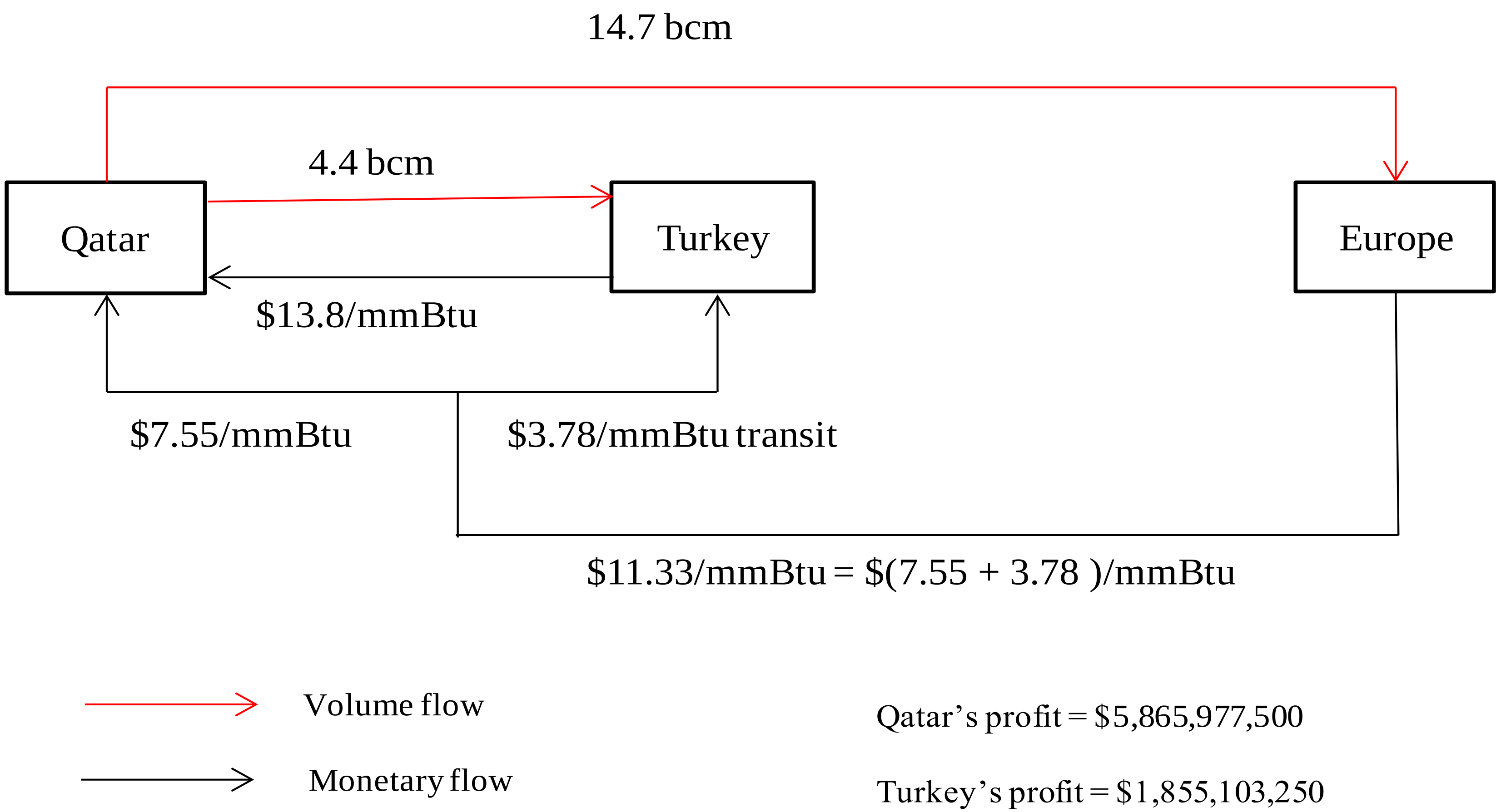




Qatar's profit = $2,684,807,537

Turkey's profit = $689,757,701

Qatar for Europe via gas pipeline Case 3 Results



Qatar's profit = $5,865,977,500

Turkey's profit = $1,855,103,250

Qatar for Europe Results 1

	Case 1	Case 2	Case 3
Price Qatar receives ($/MmBtu)	10.25 from Turkey 10.7 from Europe	9.74 from Turkey	13.8 from Turkey 7.55 from Europe
Transit fee Turkey receives ($/MmBtu)	1.8	-	3.78
Price Turkey receives ($/MmBtu)	-	13.06	-
Price Turkey pays ($/MmBtu)	10.25	9.74	13.8
Price Europe pays ($/MmBtu)	10.7	13.06	11.33
Qatar exports (Bcm)	17.2 to Europe 5.58 to Turkey	13.52 to Turkey	14.7 to Europe 4.4 to Turkey
Qatar's Profit ($)	4,140,425,250	2,684,807,537	5,865,977,500
Turkey's Profit ($)	1,032,172,000	689,757,701	1,855,103,250

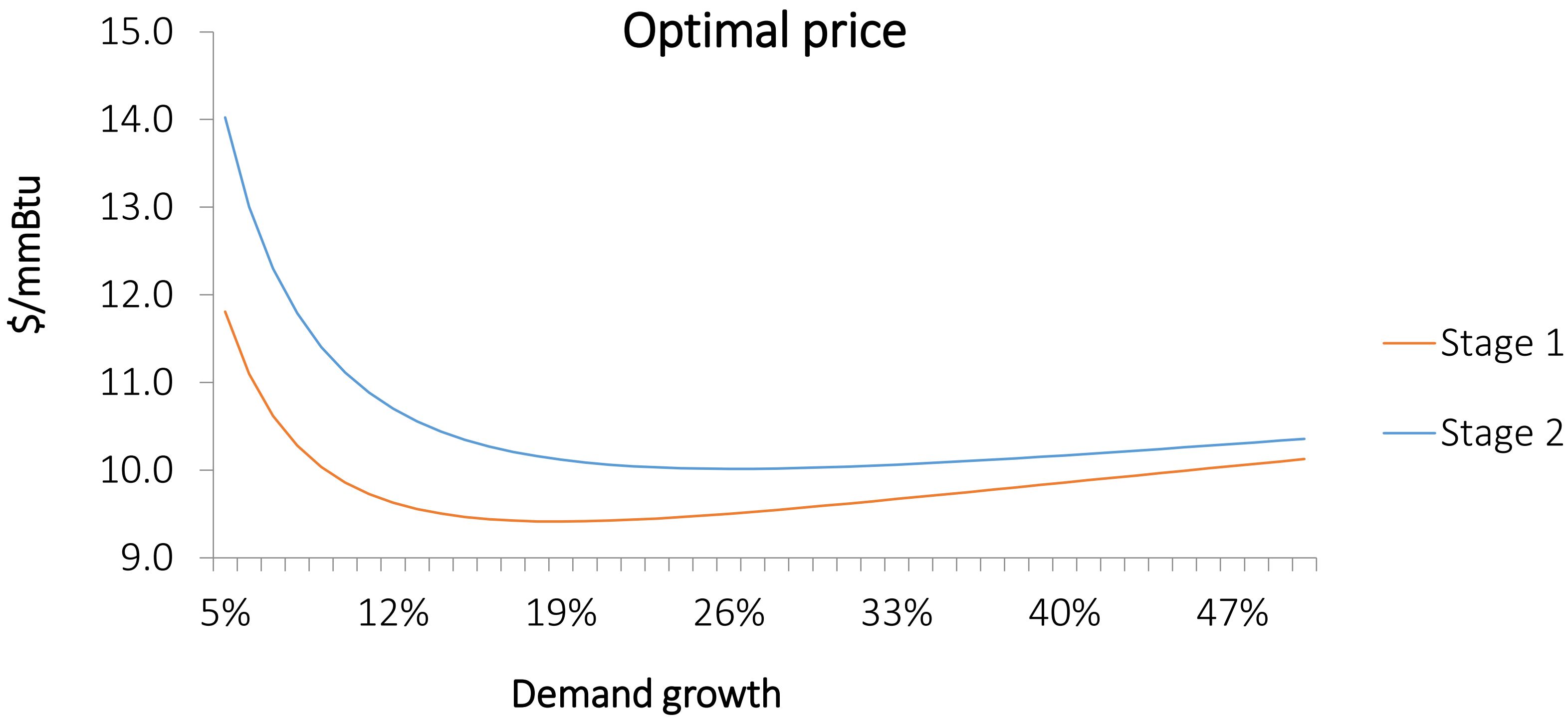
Qatar for Europe Results 2

- Qatar would not choose the second case/route where it sells all the gas to Turkey since this option is dominated by the other two.

- It would be optimal for Qatar to apply discriminating pricing on Turkey and Europe as this case yields the highest profit for both the exporter as well as the transit country.

Impact of demand growth on Russia for Asia-Pacific via LNG

- The equilibrium price of each stage is compared with that constructed under the base case assumption of 25% for Korea and Taiwan to gauge the magnitude of changing growth rates.



Impact of capacity expansion on Qatar for Europe via gas pipeline

Change in the following over base case:	Unit	Capacity expansion by 2025				
	bcm	16	17	18	19	20
Case 1 optimal price to Europe	$/mmBtu	14.20	14.95	15.58	16.08	16.45
	%	33	40	46	50	54
Case 1 optimal price to Turkey	$/mmBtu	10.25	10.25	10.25	10.25	10.25
	%	0	0	0	0	0
Case 1 optimal transit fee	$/mmBtu	4.18	5.20	6.21	7.22	8.22
	x	2.32	2.89	3.45	4.01	4.57
Case 2 optimal price to Turkey	$/mmBtu	13.67	15.04	16.16	17.10	17.89
	%	5	15	24	31	37
Case 3 optimal price to Turkey	$/mmBtu	13.8	13.8	13.8	13.8	13.8
	%	0	0	0	0	0
Case 3 optimal price to Europe	$/mmBtu	9.55	10.55	11.55	12.55	13.55
	%	26	40	53	66	79
Case 3 optimal transit fee	$/mmBtu	4.78	5.28	5.78	6.28	6.78
	x	1.26	1.40	1.53	1.66	1.79

Concluding Remarks 1

- This paper examines Russia and Qatar in future circumstances where they diversify their demand base, if the competitive landscape today persists or otherwise leading to collusive outcomes.

- Three stages are considered for Russia
  - A follower, a duopoly, and Russia/Qatar forms a monopoly and Asia-Pacific acts as a monopsony

Concluding Remarks 2

- Russia appears to set a 5.97% higher price for the Cournot stage than the Stackelberg stage, while the price for the Bilateral Monopoly stage lies in the range of $4.67 and $11.42.

- When Qatar transports gas to the European border through transit countries, results show that the multi-pricing scheme yields Qatar of about $5,865 million and in this case, European buyers have to pay $11.33/mmBtu.

Concluding Remarks 3

- The findings help importing countries (Europe and Asia-Pacific) predict exporters' behaviors and thus, gas prices are dependent on the different possible future scenarios
  - e.g., if a collusive outcome amongst exporting countries is impending, it would be ideal for importing countries to form a monopsony and increase their bargaining power
- The findings help exporters understand their competitors and transit countries, the expected profits and quantities
- The game theoretical model between Russia and Qatar is a simplified model of the real world where there are other sellers such as US (shale gas)

Thank you for your attention!

If you have any comment or suggestion, please contact me at

yhchang@suss.edu.sg