Essays on Supply Diversification of the European Natural Gas Market

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1. Introduction

1.1. Motivation

1.1.1. The increasing relevance of natural gas

Natural gas has seen a remarkable ascent: Whereas in 1965 its share in the world's primary energy consumption was 14 percent, by 2017 the share superseded 23 percent, a trend that is expected to continue (BP, 2018, IEA, 2018b). As a consequence, natural gas has become at least the second most important primary energy source behind crude oil in most of the world regions, apart from Asia Pacific where coal is the dominating primary energy source. Even in this region, natural gas demand has boomed in recent years and is likely to continue growing in the future (IEA, 2018b).

Globally, there are varying reasons for the increasing importance of natural gas: In North America, the shale gas revolution and resulting low gas prices are the main driver for an increasing natural gas demand. In fact, in many regions, natural gas is challenging coal-fired and even nuclear power generation in the electricity sector. Hence, in North America, the increasing gas demand is mainly driven by economical and technological developments like the improvement of extraction methods for hydraulic fracturing. In Asia the situation is different: The increase in natural gas demand is due to political support more than economic profitability. In Japan, e.g., the accident at the nuclear power plant in Fukushima and the resulting temporary nuclear phase out fueled a switch from nuclear to gas-fired power generation, making Japan the largest global net importer of natural gas. Also in China, the largest coal mining country in the world with plenty of coal reserves, natural gas is on the rise. Here, the increased imports of natural gas are beginning to compete with domestically mined coal to satisfy the growing energy demand, driven by the fight against local air pollution in urban areas. Especially in the industrial sector, coal is being replaced by natural gas to generate heat. By doing so, a large share of nitrate, sulfides and particulates are being avoided.

Also in Europe, the importance of natural gas is increasing, despite the fact that gas demand is expected to remain constant or increase only slightly in the next decade. The rise in importance is given by the ambitious climate policy of the European Union (EU): By 2030, 40 percent of the greenhouse gas emissions should be reduced[1]. Due to the fact that natural gas is the lowest carbon-intense fossil fuel, it is expected to help the EU to reach its climate targets in the mid-term, e.g., by substituting coal in the electricity sector. While the United Kingdom mainly phased-out

[1]In comparison to 1990.

coal with the introduction of an artificial carbon price support scheme, many western European countries have initiated a politically-motivated coal phase out. Beside the advantage of its low-carbon intensity, natural gas is also a complement to volatile renewable energy sources (RES), as natural gas power plants can be operated with more flexibility than other conventional power plants, e.g., coal-fired plants. Hence, a gas-fired power station can provide backup capacity and can easily ramp up when the wind is not blowing and the sun is not shining, i.e., when RES electricity generation falls short of covering demand. Aside from the electricity sector, natural gas can also contribute to the decarbonization of other sectors. In the heating and the mobility sectors, e.g., liquefied natural gas (LNG) could replace light heating oil in rural areas, or diesel in the heavy-duty transport.

1.1.2. The increasing European import dependency on natural gas

While the European natural gas demand is expected to remain stable or slightly increase, the European domestic gas production will continue to decline (IEA, 2018b). As a consequence, the EU import demand and, hence, the import dependence for natural gas will further increase. While today around 72 percent of the EU gas demand is imported (IEA, 2018a), it is likely that this share will increase to more than 80 percent by 2030 (Hecking et al., 2016). In 2017, around 40 percent of these imports where from one single supply country - the Russian Federation (IEA, 2018a). Furthermore, more than the half of the Russian gas was supplied via one single route, the Ukrainian pipeline transmission system. Given the relevance of natural gas for the European energy system on the one hand and the tensions between the EU, the Russian Federation and the Ukraine on the other[2], one main goal of the EU is to diversify its supply sources and supply routes (European Commission, 2019). As a consequence, the EU supports the financing of infrastructure projects like LNG import terminals or import pipelines as the Southern Gas Corridor (SGC) to incentivize the market entry of potential new suppliers. Furthermore, the EU supports infrastructure projects within Europe that promote the integration of an EU internal gas market and hence an exchange of natural gas between the member states. As such, this thesis analyzes the supply diversification of the EU natural gas market from an economic perspective.

The chapters of these thesis focus on the different options for the EU to promote a diversified gas market: Chapter 2 analyzes the effect of the Lithuanian LNG terminal that was built to diversify the Lithuanian natural gas market and break the Russian monopoly for natural gas supply in 2014. Subsequently, Chapter 3 investigates the potential of the SGC project and the role of Turkey within this project. Based on that investigation, Chapter 4 looks at the market power of transit countries and quantifies the potential of market power that Turkey may exert within the SGC. Finally, Chapter 5 investigates the EU diversification targets in general and estimates the economic effects of a realization up to 2025.

[2]The gas crisis in 2006 and 2009 as well as the Russian annexation of Crimea in 2014.

Each chapter of this thesis is based on an article to which all authors contributed equally:

- LNG Import Quotas in Lithuania – Economic Effects of Breaking Gazprom's Natural Gas Monopoly (joint work with Florian Weiser, based on Schulte and Weiser (2019a))
- Turkey's Role in Natural Gas – Becoming a Transit Country? (joint work with Istemi Berk, based on Berk and Schulte (2017))
- Natural Gas Transits and Market Power – The Case of Turkey (joint work with Florian Weiser, based on Schulte and Weiser (2019b))
- Diversification at any price? – The European Union's diversification ambitions for natural gas

The research objective and the main results are discussed in the next chapter. Thereafter, the methodology and key assumptions of each chapter are introduced.

1.2. Outline of the Thesis

1.2.1. LNG Import Quotas in Lithuania - Economic Effects of Breaking Gazprom's Natural Gas Monopoly

Chapter 2 analyzes the economic effects of the commissioning of the Lithuanian LNG terminal in Klaipėda that was financially supported by EU institutions. Together with the agreement of the LNG terminal was the decision of a yearly minimum LNG import level via a long-term contract (LTC). As a consequence of the project, Gazprom's gas monopoly in Lithuania was broken. Although the LNG of the LTC was competitively priced with an hub indexation, it had higher marginal supply costs than Russian gas. The chapter assesses the potential of such a minimum import level to mitigate the market power of a monopolistic supplier. A market consisting of a dominant supplier with low marginal supply costs and a competitive fringe with high marginal supply costs is analyzed. It is shown that there is a minimum import level for fringe supplies that optimizes the consumer surplus, which is adjusted by a compensation paid for the fringe's market entry. The developed model is parameterized for the Lithuanian gas market in 2014. It becomes clear that the decision to incentivize the market entry of high-cost LNG and thus diversify the Lithuanian gas market could be rationalized and was a feasible way to address Gazprom's market power.

1.2.2. Turkey's Role in Natural Gas – Becoming a Transit Country?

Besides supporting LNG import infrastructure that allows flexible imports from various exporters, the EU is also supporting new pipeline corridors to permanently connected suppliers to diversify its natural gas market. Chapter 3 analyzes the role of

Turkey in the Southern Gas Corridor (SGC) that consists of planned pipeline projects connecting the natural gas producers in the Caspian region and the Middle East with the European natural gas markets. The project is one of the EU's priority projects to diversify the European natural gas supply sources and routes. The pipelines to distribute the gas within the EU, but also the pipelines to bring the gas to the EU, are financially supported by EU institutions. In this chapter, Turkey's role within the project is analyzed by the simulation of different quantitative scenarios. To analyze Turkey's potential role as a transit country within this corridor, the transit volumes via Turkey to the European gas markets are quantified up to 2030. The results imply that under current conditions, i.e., a competitive environment of upstream suppliers in European gas markets leading to lower prices, Turkey's role would be of only minor importance. In accordance with various scenarios presented in this chapter, Turkey's role is seen to be most important if European future demand is more than projected and if the movement of European gas markets towards a competitive upstream environment fails.

1.2.3. Natural Gas Transits and Market Power - The Case of Turkey

Based on Chapter 3, Chapter 4 investigates Turkey's role in the SGC from another perspective. Turkey has a key role in realizing the SGC due to its geographical location. In this chapter, it is investigated to what extend Turkey may benefit from this role. The perception of BOTAŞ, the Turkish national oil and gas company, is to buy gas arriving at the Eastern borders of Turkey and sell it at a profit to European customers instead of taking a pure transit role (Skalamera, 2016). Hence, in economic terms, BOTAŞ wants to exercise market power with its gas transits (transit market power). In Chapter 4, the potential of Turkish transit market power as well as the implications for the European gas markets af investigated. In doing so, the global partial equilibrium gas market model COLUMBUS is applied. An oligopolistic and a competitive supply structure in the European upstream market in 2030 are considered in the model based on calibrations to historical gas market situations. If the European gas market in 2030 is characterized by an oligopolistic supply, Turkey is able to exert market power resulting in higher prices compared to competitive transits, in particular in South Eastern Europe. In a competitive market structure, however, due to its high supply costs the importance of the Southern Gas Corridor and thus the potential of Turkish transit market power is limited. As a policy implication, the EU could harmonize Turkey's energy laws with EU directives that guarantee a non-discriminative access to transmission grids as well as policies incentivizing contractual relations between the Southern Gas Corridor producers, Turkey and European importers. Alternatively, the EU should minimize dependencies on transit countries in general.

1.2.4. Diversification at any price? – The European Union's diversification ambitions for natural gas

While the previous chapters look at specific options or infrastructure projects to diversify the EU natural gas market, the last chapter analyzes the EU diversification ambitions in general. These are set and monitored by the Agency for Cooperation of Energy Regulators (ACER), which evaluates the level of diversification for natural gas of each EU member state. In order to do so, ACER defines several specific metrics and respective scores the metrics should fulfill. The first part will look at ACER's diversification metric, the Herfindahl-Hirschman-Index (HHI). To this end, ACER's definition of the HHI as well as its application is questioned. In the second part, a realization of ACER's predefined HHI score is simulated for the year 2025. Once again the natural gas market model COLUMBUS is extended and applied. The results show that the fulfillment of the scores would have strong implications on gas flows as well as economics. On the one hand, it would replace natural gas flows from eastern Europe, e.g., the Russian Federation, to the western Europe, e.g., LNG imports. Hence, Russia would have to reduce its natural gas supply by around one third in 2025. On the other hand, due to the ban of the low-cost Russian gas, the diversification would result in higher European natural gas prices and hence a welfare loss of 13.6 billion Euro.

1.3. Methodology

Within this thesis, different research questions regarding the supply diversification of the EU natural gas market are answered by the application of fundamental gas market models. While the investigations in Chapter 2 are based on an analytical model, the analyzes in Chapter 3 to Chapter 5 are based on numerical simulation models. However, to classify the model results into reality, it is indispensable to discuss the underlying methodologies and assumptions.

The analysis in Chapter 2 is based on a sequential model with two stages. In a first stage a country decides about a welfare maximizing import from a high cost competitive fringe that sells its output at marginal costs. In the second stage a dominant player with low costs decides about its supply to the country. The analysis is only valid for a homogeneous good like natural gas. The demand of the country is given by an inverse demand function. When the model is applied to the Lithuanian gas market linear functions for supply and demand are assumed. For the Lithuanian market it is shown that there is an economic rationale to import a certain amount from a high cost competitive fringe to effect the behavior of a dominant player. Furthermore, it is shown that the findings hold also true for more sophisticated functional demand functions as long as the functions would not be too concave and the delta between the costs of the competitive fringe and the dominant supplier would not be too high.

The analysis in the remaining Chapters 3 to 5 are based on the global gas market model COLUMBUS. COLUMBUS is an equilibrium model that is formulated as a mixed complementary problem (MCP) and allows the simulation of strategic behavior on the supply side. The demand side is modeled with price-elastic linear functions for the inverse demand. The model is calibrated using historic data and allows the simulation of the future development of the natural gas market. However, due to the uncertainty about the future, different possible scenarios are simulated in each Chapter of this thesis. Chapter 3 investigates if Turkey will become an important transit country for the EU. In general, the analysis is based on a pure economic rationale. However, due to the fact that Turkey's role as a transit country depends on different possible economic and political factors such as the future EU gas demand or supply developments, the realization of competing infrastructure projects or the connection of other potential suppliers to the SGC, several scenarios are considered. Additionally, it is assumed that Turkey as a transit country would be not able exert market power.

While in Chapter 3 Turkey itself behaved as a competitive transit country, Chapter 4 goes one step further and models Turkey as a country that potentially exerts market power with its transits against the EU by withholding gas volumes. Hereto the COLUMBUS models is extended. However, due to the resulting complexity of the model, the EU gas market is aggregated into two market areas, a north-western and a south-eastern market. A comparison of the results with Chapter 3 shows that the impact of this simplification is only minor. To cover the uncertainty about the future development of the EU supply structure, an oligopolistic and a competitive upstream sector is simulated. Again, the chapter is based on a pure economic rational. Political constraints and options are analyzed in additional scenarios.

Chapter 5 is analyzing the EU diversification ambitions by implementing ACER's HHI metric score into the COLUMBUS model. Focusing on 2025, one scenario with and one scenario without an achievement of the score is simulated. However, the HHI metric score is not implemented directly. Instead, a maximum import level for a single supplier of an EU member state is implemented. The HHI is calculated ex-post in an iterative process. However, due to the fact that is only one main supplier that is causing the height of the HHI, the implementation of a maximum supply share is adequate. The same is true for the assumption that in COLUMBUS, countries and not companies are modeled due to the fact that the main supply countries can be associated with one major export company, e.g., Russia with Gazprom or Algeria with Sonatrach.

The discussion of the methodology within this section solely provides a general overview. Within each chapter, the respective methodology is discussed in more detail. Furthermore, a detailed description of the COLUMBUS model is provided by Hecking and Panke (2012) as well as in the Appendix.

2. LNG Import Quotas in Lithuania - Economic Effects of Breaking Gazproms‘s Natural Gas Monopoly

Until 2014, Russia's Gazprom had a natural gas monopoly in Lithuania. In order to break the Russian monopoly, the Lithuanian state financed an import terminal for liquefied natural gas (LNG) in Klaipėda. In addition to building the terminal, Lithuania signed a long-term contract (LTC) which can be interpreted as a minimum import volume quota for LNG having higher marginal supply costs than Russian gas. This chapter assesses the potential of such a minimum import volume quota to mitigate the market power of a monopolistic supplier. A market consisting of a dominant supplier with low marginal supply costs and a competitive fringe with high marginal supply costs is analyzed. It is shown that there is a minimum import volume quota for fringe supplies that optimizes the consumer surplus, which is adjusted by a compensation paid for the fringe's market entry. Therefore, the Lithuanian decision to incentivize the market entry of high-cost LNG can be rationalized.

2.1. Introduction

In recent years, natural gas prices in Eastern Europe have been significantly higher than in Central or Western Europe (ACER, 2016), primarily due to the dominant position of Russia's gas exporter Gazprom in the Eastern European gas markets (Henderson and Mitrova, 2015). As of 2013, several European Union (EU) member states were subject to a Russian gas supply monopoly: Lithuania, Latvia, Estonia and Finland (ACER, 2014). Apart from the economic disadvantages resulting from Gazprom's monopoly, political actors in those countries feared that Russian gas deliveries could be used as a political tool by the Russian administration. Against this background, Lithuania, built an import terminal for liquefied natural gas (LNG) in Klaipėda in 2014 with financial support from the EU to allow LNG suppliers access to their market, thus breaking Gazprom's monopoly (Pakalkaitė, 2016).

Although the political goal of supply diversification was achieved by this measure, an economic assessment of the terminal crucially depends on global LNG market developments.[1] Lithuania secured a long-term contract (LTC) with the Norwegian supplier Statoil in 2014 to provide must-run LNG imports ensuring the continuous utilization of the newly built terminal. The marginal supply costs of Gazprom were

[1]LNG is a global commodity as analyzed by e.g. Barnes and Bosworth (2015).

generally considered to be much lower than those of LNG, which has to be liquefied, transported by ship and regasified at the destination. In addition, there was a global scarcity of liquefaction plants in the mid 2010s, which led to a high utilization of existing plants and an increase in LNG prices compared to previous years (International Gas Union, 2015).

The objective of this chapter, therefore, is to investigate the economic rationale behind the Lithuanian policy to incentivize must-run imports of high-cost LNG. Such incentives may not be necessary in the case of comparably low LNG prices, i.e. LNG would be imported without a minimum import requirement if an LNG import terminal has been constructed. However, the LTC leads to economic disadvantages for the owner of the LNG terminal if LNG import prices are higher than the gas price paid to the dominant supplier. If the owner of the LNG terminal is the state, as is the case in Lithuania, the potential losses generated by the LNG imports are then passed on to the citizens or gas customers in one way or another. Hence, one would intuitively think that securing a LTC for LNG may induce additional burdens for gas customers in situations with comparably high LNG import prices. However, the chapter at hand argues that a minimum import requirement for LNG could enhance Lithuanian national welfare[2] even if the LNG import prices would be above the former Russian monopoly price. This is due to the reaction of the dominant supplier on the market intervention. Hence, the Lithuanian decision to build the terminal and sign a LTC can be rationalized as a feasible instrument to address Gazprom's market power.

Generally speaking, our analysis investigates a market consisting of a dominant supplier with low marginal supply costs and a competitive fringe with high marginal supply costs. In this setting, a minimum volume quota[3] for the fringe supply is considered. It is shown that a minimum volume quota can increase the consumer surplus of an importing country adjusted by the compensation payments necessary to introduce the quota.

The structure of the chapter is as follows: Section 2.2 gives an overview of the literature relevant for this analysis. Section 2.3 focuses on a stylized model in which the implications of a minimum volume quota are discussed analytically. In Section 2.4, the model is applied with parameters characterizing the Lithuanian gas market in 2014. Finally, Section 2.5 concludes.

2.2. Literature Review

There are two aspects of our research that, to the best of our knowledge, have yet to be investigated in the literature. First, a minimum import volume quota for a high-cost fringe as a trade policy instrument to increase the consumer surplus of a

[2] Due to the fact that Lithuania does not have indigenous natural gas resources and thus no production, national welfare is identical to the consumer surplus.

[3] A volume quota means that a fixed amount of fringe volume needs to be imported in the market. A share quota, however, would mean that a certain share of the demand needs to be supplied by the fringe.

national market is a novelty. Second, the application of this policy instrument to the Lithuanian natural gas market is new. We have identified three different branches of literature that are relevant for our investigation: 1) literature on (strategic) trade theory, 2) industrial organization literature focusing on fringe-firm intervention and multiple sourcing, and 3) literature on the Lithuanian natural gas market.

Strategic trade theory (also referred to as "strategic trade policy") investigates policy instruments affecting the output of a dominant foreign firm. Within the literature, there exist several studies analyzing the effects of tariffs and quotas for the national welfare of a country. The first seminal work to examine the equivalence of different trade restrictions was Bhagwati (1965). He shows equivalence of tariffs and quotas for a market configuration with a dominant foreign firm and a domestic producer that is assumed to be competitive. Based on his findings, but relaxing the assumption of a competitive domestic producer, Shibata (1968), Yadav (1968) and Bhagwati (1968) show non-equivalence of tariffs and quotas because the domestic producer benefits from monopoly power under a quota. Furthermore, Hwang and Mai (1988) illustrate that the equivalence of tariffs and quotas also depends on the market behavior of the firms analyzed. By using a conjectural variation approach with different conjectures, they expose that equivalence holds only for the Cournot case. Other works investigate quotas and tariffs separately. Brander and Spencer (1981), for instance, analyze tariff policies in an imperfectly competitive market. They show how a tariff can be used to extract rents from a foreign exporter. Moreover, their results illustrate the benefits regarding the national welfare of using a tariff to support the market entry of a domestic firm. Eaton and Grossman (1986) focus on Bertrand competition rather than Cournot competition analyzing the welfare effects of trade policy under oligopoly. They find that a tax optimizes national welfare with Bertrand competition. Breton and Zaccour (2001) focus on import quotas in an abstraction of European gas markets in the 1980s. They consider an asymmetric oligopoly with a diversification constraint on a player representing the Soviet Union. Krishna (1989) studies the effect of an import quota in a duopoly of a home firm and a foreign firm. He examines the increasing profitability of a home firm that is able to raise its prices when imports are restricted. He shows that the home consumers are the losers of the maximum import quota.

The aforementioned literature analyzes instruments having a direct effect on the dominant supplier. A minimum quota in this chapter supports the market entry of the high-cost supplier and has thereby only an indirect effect on the output of the dominant firm. A similar effect is examined by Brander and Spencer (1985): Based on a two stage game, they show that export subsidies may be an attractive trade policy instrument from a domestic point of view. While governments set subsidies in a first stage, firms set their output levels based on the subsidy and on the rivals' output in a second stage. The results of Brander and Spencer (1985) illustrate that the export subsidy lowers a good's world price and increases the domestic firm's profit by extracting rents from the foreign firm. Whereas the subsidy analyzed in the work of Brander and Spencer (1985) supports the domestic producer, the chapter at hand considers a minimum import quota to incentivize the entry of an external high-cost competitive supplier. A recent application of strategic trade theory to gas markets in a cooperative game theory framework is Ikonnikova and Zwart (2014). Similar to our analysis, they focus on a setting in which both buyers and sellers have market power. They find that trade restrictions like quotas can increase buyers' countervailing market power. However, their focus is on strategic externalities among several buyers, whereas this chapter concentrates on a single pair of buyer and dominant seller in a non-cooperative game theory framework.

A further stream of literature that is relevant for this analysis can be clustered under the concepts of multiple sourcing and fringe-firm intervention as part of the literature on partial industry regulation. According to Ayres and Braithwaite (1992), fringe-firm intervention means that a regulator or private company supports the entry of a competitive fringe into a market with a dominant player. In line with Stigler (1964) and Tirole (1988), an increasing number of competitors in a market results in increasing competition. Hence, competition is induced without a direct regulatory restrain to the dominant firm. Examples for markets in which fringe-firm intervention takes place are the defense or the automotive industry, e.g. Riordan and Sappington (1989), Farrell and Gallini (1988), Anton and Yao (1987) and Demski et al. (1987). However, literature on fringe-firm interventions of private companies is limited because private companies are faced with a free-rider problem: If one company decides to support the market entry of a competitive fringe, and the fringe produces an input for the company, also the company's competitors would benefit. Moreover, the examples provided in the literature focus on complex and differentiated goods as defense systems. In our work we analyze the market for natural gas, which is a homogeneous good. An import quota as investigated in the following, is only applicable to a homogeneous good.

There are only a few contributions in the literature on resource markets addressing the Lithuanian energy market. Works that include the Baltic gas markets in analyzing the European gas security of supply are e.g. Richter and Holz (2015) and Baltensperger et al. (2017). Hinchey (2018) discusses Russian natural gas pricing in Europe in the presence of alternative supply options for gas. In doing so, a special focus is put on the Lithuanian LNG terminal. Similar to our chapter, Hinchey (2018) finds that importing LNG was economically rational for Lithuania. However, her focus is rather on a bargaining solution than on a non-cooperative game. In addition, compared to the analysis of Hinchey (2018) who only examines prices, this chapter evaluates the welfare impacts of LNG imports for the Lithuanian gas market.

2.3. Theoretical Model

Before the Lithuanian natural gas market is analyzed in more detail, the effect of a minimum import quota on a market for a homogenous good is analyzed within a theoretical framework. First, general functional forms of the cost and supply functions in the model are considered. Later on, linear simplifications for those functions are used.

2.3.1. General Model Setup

A country demands a homogeneous good q from abroad. The demand is given by $q(p)$, and $p(q)$ is the inverse demand function. The law of demand is assumed to hold.

There are two sources for the good: (i) a dominant supplier D and (ii) a competitive fringe F. The cost functions of both supply sources $C_D(q)$ and $C_F(q)$ are convex. The dominant supplier is more cost efficient than the competitive fringe, i.e. has lower marginal supply costs: $C_D'(q) < C_F'(q)$. The importing country considers introducing a quota L for imports from the competitive fringe. The question is whether a quota increases national welfare, and how it is optimally chosen. We analyze this in a two stage interaction model. In the first stage, L is determined by the country with the objective to maximize national welfare, which is equivalent to the consumer surplus in the absence of indigenous production. Afterwards, there is supply by the dominant supplier and the fringe firms.[4]

Fringe firms sell their output at the marginal cost $C_F^{'} = \frac{\partial C_F(L)}{\partial L}$ to meet the quota, i.e. their output equals exactly the quota L. Thus, the country's expenditures for the import from the fringe firms will be $L \cdot C_F^{'}(L)$. The dominant supplier takes the quota as given and maximizes profit with respect to the residual demand $q_R(p) = q(p) - L$. Graphically, the residual demand is a parallel shift of the demand function. The dominant supplier chooses a quantity q_D^*:

$$q_D^* \in \arg\max_{q_D} p(q_D + L) \cdot q_D - C_D(q_D). \tag{2.1}$$

The optimal q_D^* is a function of L. The country chooses L^* to maximize national consumer surplus adjusted by a compensation paid to the fringe firms (from now on called "adjusted consumer surplus"):

$$L^* \in \arg\max_{L} CS(L), \tag{2.2}$$

$$\text{where } CS(L) = \int_0^{q_D^*+L} p(x)\,dx - p\left(q_D^*\right) q_D^* - LC_F^{'}(L). \tag{2.3}$$

Assuming an interior solution, the optimal national quota is given with $C_F^{''} = \frac{\partial^2 C_F(L)}{\partial L^2}$ by:

[4] Similar to the game in the seminal analysis of Brander and Spencer (1985), the country's action takes place before the firm's actions. Brander and Spencer (1985) mention that the market intervention announced by the government is assumed to be credible as the reason why the country is able to move first.

$$\frac{\partial CS}{\partial L} = \left(1+\frac{\partial q_D^*}{\partial L}\right) p\left(q_D^*+L\right) - \frac{\partial q_D^*}{\partial L}\left(\left.\frac{\partial p}{\partial q_D}\right|_{q_D=q_D^*} \cdot q_D^* + p\left(q_D^*\right)\right) - C_F^{''}L - C_F^{'}=0. \tag{2.4}$$

This can be reformulated as follows:

$$p\left(q_D^*+L\right) - C_F^{'} - C_F^{''}L = -\frac{\partial q_D^*}{\partial L} p\left(q_D^*+L\right) + \frac{\partial q_D^*}{\partial L}\left(p\left(q_D^*\right) + \left.\frac{\partial p}{\partial q_D}\right|_{q_D=q_D^*} \cdot q_D^*\right). \tag{2.5}$$

On the left hand side of equation (2.5), there is the change in consumer surplus due to receiving one (marginal) unit more from the fringe firms when (marginally) increasing the quota: The first term represents the additional consumer surplus, the second term the cost for the additional unit, and the third term the change in cost for all inframarginal units bought from the fringe. On the right hand side, there is the change from the reaction of the dominant supplier. If the supply of the dominant supplier decreases ($\partial q_D^*/\partial L < 0$), the consumer surplus is reduced (first term). However, less supply from the incumbent saves the cost for this reduced supply (first part of the expression in brackets in the second term) but also drives up the price for all inframarginal units (second part of the expression in brackets in the second term).

A strictly positive quota $L > 0$ is optimal, if the following condition holds:

$$\left.\frac{\partial CS}{\partial L}\right|_{L=0} = \left(1+\frac{\partial q_D^*}{\partial L}\right) p\left(q_D^*\right) - C_F^{'}(0) - \frac{\partial q_D^*}{\partial L}\left(\left.\frac{\partial p}{\partial q_D}\right|_{q_D=q_D^*} \cdot q_D^* + p\left(q_D^*\right)\right) > 0. \tag{2.6}$$

Proposition 2.1. *A strictly positive quota, $L > 0$, increases the importing country's adjusted consumer surplus if (a) the fringe firms' marginal costs are not too high, i.e. $C_F^{'}(0) < \left(1+\frac{\partial q_D^*}{\partial L}\right) p\left(q_D^*\right) - \frac{\partial q_D^*}{\partial L}\left(\left.\frac{\partial p}{\partial q_D}\right|_{q_D=q_D^*} \cdot q_D^* + p\left(q_D^*\right)\right)$, and (b) the inverse demand function is not too convex, i.e. $\frac{C''-p'}{q_D^*} > p''$.*

Proof. The first order conditions of the dominant supplier's problem are given by:

$$\frac{\partial p}{\partial q_D} q_D + p\left(q_D+L\right) - \frac{\partial C_D}{\partial q_D} = 0. \tag{2.7}$$

Thus, for an interior solution q_D^* satisfying this condition, the implicit function theorem implies

$$\left.\frac{\partial q_D}{\partial L}\right|_{q_D=q_D^*} = \frac{-p'}{p''q_D^* + 2p' - C_D^{''}}. \tag{2.8}$$

The numerator of the right hand side of equation (2.8) is positive because p' is negative due to the law of demand. The denominator, however, is negative because of the second order conditions of the dominant supplier's problem. Hence, the total expression on the right hand side of equation (2.8) is negative. The right hand of equation (2.8) is larger than -1 if and only if $C'' - p' > p'' q_D^*$, which holds as long as p'' is not too large, i.e. if the inverse demand function is not too convex. In that case, $0 > \frac{\partial q_D^*}{\partial L} > -1$ holds. This means that the first and the third term of equation (2.6) are strictly positive (note that the dominant supplier's optimization implies that the expression in brackets in the third term is weakly larger than the (positive) dominant supplier's marginal costs). In that case, the left hand side of equation (2.6) is positive if $C_F^{'}(0)$ is not too large. □

The requirement that the fringe's marginal costs should not be too high intuitively makes sense. Importing fringe volume by the quota is more expensive, the higher the marginal costs of the fringe. The condition about the convexity of the inverse demand function, however, is more difficult to interpret intuitively because there are two opposing effects: 1) A very convex inverse demand function implies that a parallel leftward shift of the inverse demand will ceteris paribus lead to higher outputs by the dominant supplier (for any q_D, the slope of the inverse demand is flatter, and placing additional units in the market requires a smaller decrease of price). This leads to a decrease in price. 2) However, the additional consumer surplus due to the decrease in price is small if the inverse demand is very convex. Then, a situation can occur in which the compensation paid to the fringe exceeds the additional consumer surplus leading to a negative total effect.

Besides the impact of the quota on the importing country's adjusted consumer surplus, the total welfare (including the producer surplus of the dominant supplier and the fringe firms) is of interest. The welfare is defined as:

$$W(L) = \int_0^{q_D^* + L} p(x)\,dx - C_D\left(q_D^*\right) - C_F(L). \tag{2.9}$$

As shown in A.1, the welfare does not increase if a positive volume quota is introduced.

2.3.2. Optimal Quota for Linear Inverse Demand and Cost Functions

As a simplification, we now assume a linear inverse demand function:

$$P(q_D + L) = \alpha - \beta \cdot (q_D + L). \tag{2.10}$$

Additionally, linear cost functions for the dominant supplier D and the fringe F are assumed:

$$C_i(q_i) = a_i + C_i' \cdot q_i \text{ for } i = D, F. \tag{2.11}$$

Plugging this into equation (2.5), we get:

$$L^* = -\frac{1}{\beta} \cdot C_F' + \frac{\alpha}{\beta} + q_D^* \cdot \frac{\partial q_D^*}{\partial L}. \tag{2.12}$$

Equation (2.8) becomes for the linear simplification: $\frac{\partial q_D^*}{\partial L} = -\frac{1}{2}$. Then, the following solution is obtained:

$$L^* = -\frac{1}{\beta} \cdot C_F' + \frac{\alpha}{\beta} - q_D^* \cdot \frac{1}{2}. \tag{2.13}$$

$$q_D^* = \frac{C_F' - C_D'}{\frac{3}{2}\beta}. \tag{2.14}$$

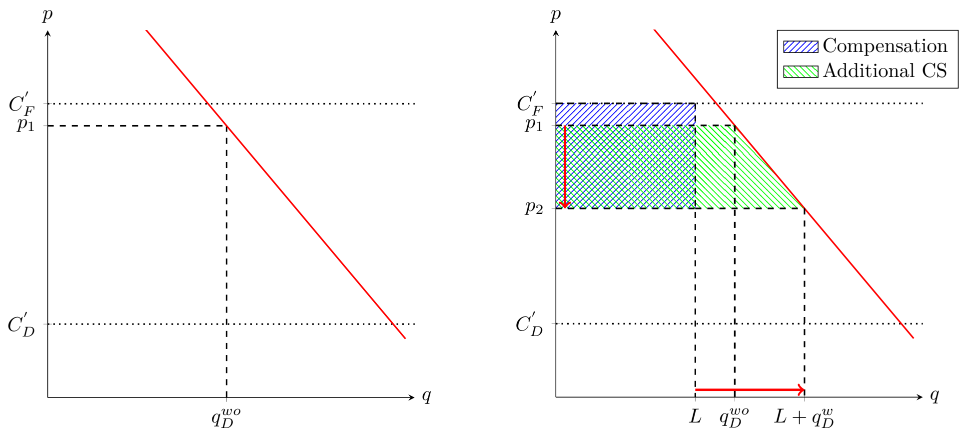

Figure 2.1.: Market without a quota (left hand side) and with a quota (right hand side)

Figure 2.1 illustrates the effect of the minimum import quota schematically for linear inverse demand and cost functions. On the left hand side, the situation without a quota is shown. No fringe volumes enter the market due to the fringe's high constant marginal supply costs. On the right hand side, the quota has been introduced. It can be seen that the volumes supplied by the dominant supplier are reduced by the introduction of the quota. However, because the dominant supplier has market power, the reduction of her volume, $\frac{L}{2}$, is lower than the quota volume, L. Hence, the total supplied volumes increase by the introduction of the quota leading to a decrease in price and to additional consumer surplus. However, since the marginal supply costs of the fringe exceed the resulting market price, the fringe firms must be compensated for the difference between the market price and marginal supply costs. Although the additional consumer surplus is reduced by this compensation, there is still a positive effect on the consumer surplus.

After it was shown in general that it is possible to design volume quotas optimizing the consumer surplus adjusted by payments to the fringe firms, the introduced model is applied to the case of the Lithuanian gas market in the next section.

2.4. Application to the Lithuanian Natural Gas Market

As outlined in the introduction, the Lithuanian gas market changed in 2014 from a monopoly structure to a market structure with a dominant supplier having low marginal supply costs and a competitive fringe having high marginal supply costs. In addition, Lithuania signed a LTC for LNG, which can be interpreted as a minimum volume quota for LNG allowing us to apply the theoretical considerations developed in Section 2.3 to the Lithuanian gas market.

2.4.1. Background

In absence of natural gas resources, Lithuania is 100% dependent on imports. Because the country was a former part of the Soviet Union, its only import pipeline is connected to Russia. Prior to December 2014, when the LNG import terminal in Klaipėda started operation, Gazprom had a monopoly for gas sales to Lithuania, which resulted in comparably high gas prices (ACER, 2015a). In the fourth quarter of 2014, the Lithuanian gas price was 408 € /1000m^3, whereas the gas price at the Dutch hub Title Transfer Facility (TTF), the most liquid European gas hub, was 247 € /1000m^3 (European Commission, 2014).

In addition to building the LNG terminal, Lithuania signed a LTC with Norway's Statoil with an annual contracted quantity (ACQ) of 0.55 bcm and a take-or-pay (TOP) volume of 0.44 bcm of LNG.[5] The LNG price was based on the natural gas price of the National Balancing Point (NBP), the natural gas hub of the United Kingdom, with a surcharge (Pakalkaitė, 2016).

Historically, the purpose of LTCs in the gas industry was to mitigate price and volume risks and ensure the usage of certain infrastructure elements, e.g. pipelines and LNG terminals. In the Lithuanian case, this may have been a motivation behind signing the LTC, too. However, it is clear that the LTC would be a bad decision from the point of view of a profit optimizing terminal owner if the marginal supply costs of LNG would be above the gas price in the Lithuanian gas market (the price having to be paid to Gazprom). Because the marginal supply costs of LNG are higher than the marginal supply costs of Russian gas, there is indeed the risk of such unfavorable market conditions for the LNG terminal. Therefore, it is unlikely that private actors would have financed a LNG terminal in Lithuania. Indeed, no actor other than the Lithuanian state took the risk of the investment. The costs of the investments were passed on to the gas customers by supplements on gas (Pakalkaitė, 2016). However,

[5] It is assumed that the TOP volume is 80 percent of the ACQ. This is a typical annual flexibility for LTCs (Franza, 2014).

even in the absence of a private business case for the terminal, the enhancing effects of minimum import quotas for the consumer surplus discussed in Section 2.3 indicate that the decision of the Lithuanian state to build the terminal and sign a LTC can be rationalized from a domestic point of view.

The assumptions of the model framework described in Section 2.3 fit well for the Lithuanian gas market. Due to the coupling of the LTC prices to the NBP, the LNG imports can be assumed to be competitively priced, even though the LTC was secured with only one company. As in the theoretical model, capacity constraints of the gas infrastructure are not relevant for Lithuania. The pipeline connection from Russia allows imports of more than 10 bcm/a and the LNG terminal has a regasification capacity of 4 bcm/a (Gas Infrastructure Europe, 2017), whereas the Lithuanian gas demand was only 2.54 bcm in 2014 (IEA, 2016).[6]

2.4.2. Initial Monopoly Situation

In this subsection the monopoly situation before the construction of the LNG terminal is considered. The analysis is based on linear functions for the inverse demand and supply costs.[7]

In line with Bros (2012), marginal costs for Russian gas of 0.07 €$/m^3$ are assumed.[8] We introduce a reference price P_{ref}, a reference demand D_{ref} and a point measure for the price elasticity of demand ϵ. The parameters of the inverse demand function α and β can be related to those parameters:

$$\beta = -P_{ref}/D_{ref}/\epsilon, \tag{2.15}$$

$$\alpha = P_{ref} + \beta \cdot D_{ref}. \tag{2.16}$$

Due to the fact that the Lithuanian LNG terminal was commissioned in December of 2014, it is assumed that the average price and demand situation in 2014 still corresponded to a monopoly situation. With the historic demand of 2.54 bcm and the price of 394 €$/1000m^3$ that is the weighted average price of Russian gas deliveries

[6]Even if the interconnection point between Lithuania and Latvia in Kiemėnai having a capacity of 2 bcm/a would be fully used to reexport gas from Lithuania, Russian import pipeline capacities would still be sufficient to cover the Lithuanian demand and the reexports to Latvia.

[7]In order to quantify the effects of a minimum import quota, certain functional forms for the demand and supply curves have to be considered. Linear functions are a straightforward approach, since any function can be approximated by a linear function in a small range around a certain point. However, as shown in the previous section, more sophisticated functional forms would not change the key result there is a rationale behind incentivizing the LNG imports to Lithuania as long as the demand function would not be too concave and the marginal costs of the LNG suppliers would not be too high.

[8]This includes the Russian gas production costs, mineral extraction tax and transportation costs in Russia. However, the Russian export duty is not included as a cost component because it is considered to be part of the Russian producer surplus from exporting gas.

Table 2.1.: Characteristics of the Lithuanian gas market in 2014

Parameter	Value	Unit
$C_D^{'}$	70	€/1000m^3
P_{ref}	394	€/1000m^3
D_{ref}	2.54	bcm
ϵ	-1.22	-
CS	411	million €
Φ	822	million €

to Lithuania in 2014 (European Commission, 2016) the point elasticity is chosen so that the monopoly quantity matches the reference demand. Then, the monopoly price also corresponds to the reference price by construction. This value of the point elasticity is given by:

$$\epsilon = \frac{P_{ref}}{C_D^{'} - P_{ref}}. \tag{2.17}$$

With the parameters discussed above, this results in a point elasticity of -1.22.[9] As can be seen in Table 2.1, this parameterization leads to a Russian profit Φ of 822 million Euro while the Lithuanian consumer surplus CS is 411 million Euro. After discussing the monopoly situation, the impact of LNG imports on the Lithuanian market will be analyzed in the next section.

2.4.3. The Effects of a minimum LNG Import Quota

Based on the inverse demand function of 2014, the Lithuanian decision to sign the LTC for 0.44 bcm/a of LNG is now evaluated. Because the marginal supply costs $C_F^{'}$ of LNG were uncertain when the LTC was signed, market implications of LNG imports are discussed in dependence on the costs $C_F^{'}$.

[9]This is close to -1.25, which is the empirically determined value for the long-run price elasticity of natural gas demand according to Burke and Yang (2016). As also mentioned by Burke and Yang (2016), the literature reports small (inelastic) values for the price elasticity in the short-run. Especially for households, the demand is usually assumed to be very inelastic in the short-run due to the requirement to heat in the cold period of the year. Since a monopolist chooses a point on the elastic segment of the demand function according to basic economic theory, it seems plausible that his pricing behavior is rather determined by the long-run price elasticity of demand.

The left hand side of Figure 2.2 illustrates the Lithuanian LNG import volumes when the costs $C_F^{'}$ are varied. The figure shows three different setups: (1) imports without a quota (solid graph), (2) imports with the quota of 0.44 bcm/a as introduced by the Lithuanian government (dashed graph), and (3) imports with an optimal quota maximizing the adjusted consumer surplus as described in Section 2.3 (dashed-dotted graph). Without a quota, LNG enters the market at costs $C_F^{'}$ lower than the monopoly price of 394 €/1000m^3, whereas no LNG imports would take place if the costs $C_F^{'}$ would be above the monopoly price. However, with the Lithuanian quota, at least 0.44 bcm of LNG would be imported irrespective of the costs $C_F^{'}$. With the optimal quota, more LNG compared to the two other illustrated cases would be imported. For instance, the optimal minimum import quota would be approximately 1.7 bcm at the monopoly price.

The right hand side of Figure 2.2 shows the development of Russian gas imports in dependence on the marginal supply costs for LNG for the case without a quota, with the Lithuanian quota and an optimal quota. Obviously, a binding import quota for LNG lowers the gas imports from Russia compared to the case without a quota.

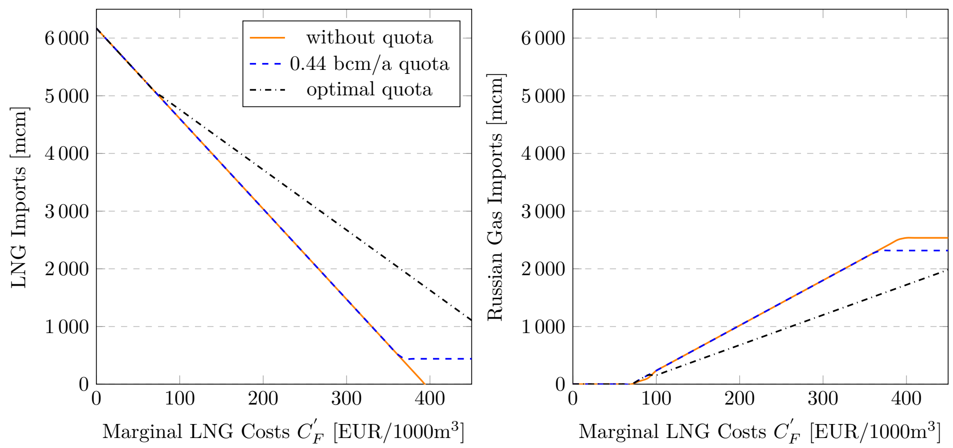

Figure 2.2.: LNG imports (left hand side) and Russian gas imports (right hand side) in dependence on $C_F^{'}$

After discussing the implications of a minimum quota on import volumes, the effects on gas prices are analyzed in a next step. Hereto, Figure 2.3 shows the Lithuanian gas price in dependence on the LNG costs $C_F^{'}$. As long as the import requirement is over-fulfilled, the prices without a quota and with the Lithuanian quota (solid and dashed graphs) are matching and correspond to the costs $C_F^{'}$. In other words, the marginal supply costs of LNG set the price in the Lithuanian gas market. However, at high costs $C_F^{'}$, the Lithuanian gas price with the quota of 0.44 bcm/a is lower than the gas price without a quota. In such situations, private owners of the LNG import terminal would generate a loss because their expense per imported LNG unit, $C_F^{'}$, would be above the price in the market. In 2014, the average global LNG price was approximately 445 €/1000m^3 (International Gas Union, 2015). Hence, LNG prices above the Lithuanian monopoly price were historically already observed. With an optimal import quota, the Lithuanian gas price is below the price without a quota as long as the marginal LNG costs $C_F^{'}$ are above the dominant supplier's marginal costs $C_D^{'}$.

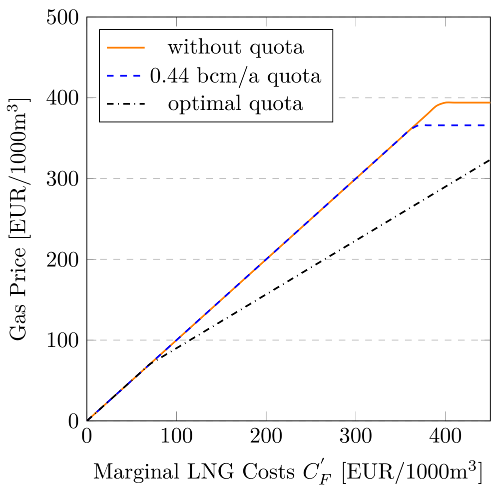

Figure 2.3.: Lithuanian gas price in dependence on $C_F^{'}$

Besides gas prices, the influence of the LNG import quota on the Lithuanian consumer surplus adjusted by the payment for the LNG imports is analyzed. Figure 2.4 illustrates the adjusted consumer surplus in dependence on the marginal supply costs $C_F^{'}$. In line with the conventions in the previously discussed diagrams, the function illustrated by the dashed graph indicates the adjusted consumer surplus with the Lithuanian import quota of 0.44 bcm/a, whereas the dashed-dotted graph describes the situation with an optimal quota. The solid graph is the benchmark of no quota. For values of $C_F^{'}$ above the monopoly price of 394 €/1000m^3, the solid graph corresponds to the consumer surplus in the monopoly case. The solid and the dashed graphs match for low $C_F^{'}$ when more LNG than 0.44 bcm/a is imported and the quota is therefore over-fulfilled. However, at high $C_F^{'}$, a binding volume quota leads to additional consumer surplus. While no disadvantages of the quota occur with low $C_F^{'}$, advantages can be realized if high LNG supply costs lead to a situation in which the dominant supplier could still exercise market power in the absence of minimum import requirements.

Figure 2.2, Figure 2.3 and Figure 2.4 suggest that the actual Lithuanian import quota of 0.44 bcm/a would be below the optimal quota. However, if $C_F^{'}$ would be too high, the change in adjusted consumer surplus relative to the monopoly case could become negative for a given value of a quota. The dashed graph in Figure 2.4 intersects with the solid graph at $C_F^{'} = 535$ €/1000m^3. For higher $C_F^{'}$, the quota of 0.44 bcm/a would not enhance the Lithuanian national welfare anymore. For larger

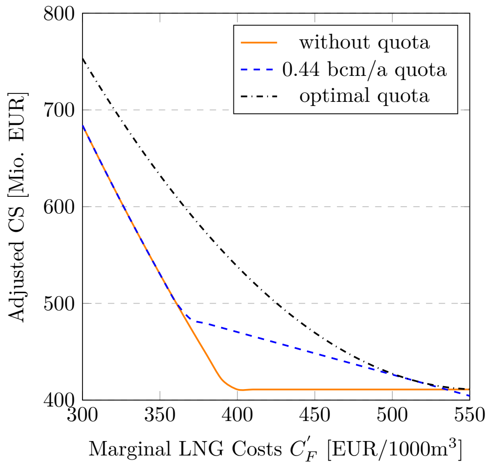

Figure 2.4.: Lithuanian adjusted consumer surplus in dependence on $C_F^{'}$

quotas than 0.44 bcm/a, this threshold value of $C_F^{'}$ is lower. For instance, the optimal quota at the monopoly price of approximately 1.7 bcm (cf. Figure 2.2) would lead to a negative national welfare effect already at a value of $C_F^{'} = 477€/1000m^3$. Hence, committing to import a high minimum volume leads to the risk that the difference of the adjusted consumer surplus relative to the monopoly case becomes negative at high $C_F^{'}$. Risk averse actors may therefore prefer to commit to a comparably small volume for the quota. Alternatively, the importers could introduce quotas with volume flexibility, i.e. require additional imports in situations with low $C_F^{'}$ and require reduced imports in situations with high $C_F^{'}$.

The construction costs of the Klaipėda terminal add up to 101 million EUR, and a yearly lease of 55.3 million EUR needs to be paid (The Baltic Course, 2015). If we assume a life time of the investment of 20 years and an exemplary discount rate of 8%, the yearly annuity for the investment costs is 10.3 million EUR. Hence, the total yearly fixed costs of the terminal amount to 65.3 million EUR. The benchmark of the consumer surplus in the monopoly case is 411 million EUR. As can be seen in Figure 2.4, the additional consumer surplus due to the LTC of 0.44 bcm/a is in the same range as the total yearly fixed costs of the terminal if $C_F^{'}$ is in the range between 380 and 400 $€/1000m^3$. At $C_F^{'}$ below 380 $€/1000m^3$, the quota of 0.44 bcm/a would be over-fulfilled. Nevertheless, the consumer surplus would increase significantly compared to the monopoly case due to the competitiveness of the LNG imports.

Figure 2.5 shows the development of the welfare (with consideration of the producer surplus of the dominant supplier and the fringe firms) in the cases without an import quota for LNG, with a quota of 0.44 bcm/a and with an optimal quota. It can be seen that the imposition of a binding quota leads generally to a lower welfare compared to the case without a quota (cf. A.1 for a formal discussion of the welfare implications of a quota). In the monopolistic case, the welfare amounts to 1.2 billion

EUR. With perfect competition (the dominant supplier and the fringe firms bid their marginal supply costs), however, the welfare would be at 1.6 billion EUR.

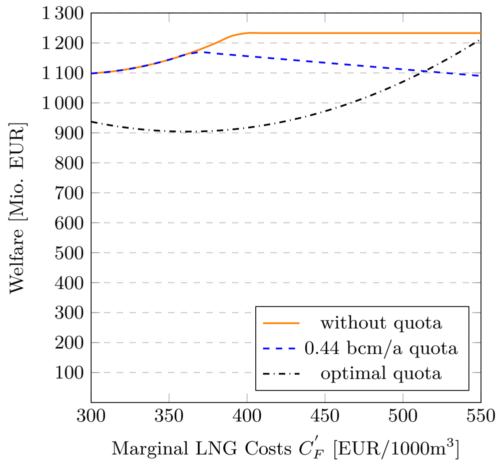

Figure 2.5.: Welfare in dependence on $C_F^{'}$

While it is intuitive that the total welfare is lowered by the quota, our analysis shows that the national welfare in Lithuania could be enhanced by this measure. Besides the economic advantages, an additional positive effect of the quota is an increased security of supply in Lithuania due to the diversification of supplies (away from Russian gas).

2.4.4. Discussion of Results

In order to evaluate the Lithuanian strategy to mitigate Gazprom's market power, alternative concepts to reduce market power should be considered. Such other potential strategies include, e.g., a further integration of markets by additional pipeline connections[10], gas release auctions and unbundling of the dominant supplier. Economic theory indicates that the most efficient way to mitigate market power would be to set a maximum price being equal to the marginal supply costs of the dominant supplier if those were known. From a practical point of view, however, unilateral actions of authorities (e.g. regulator, government) against the dominant supplier potentially give rise to the risk that the dominant supplier cuts off the supply. In particular, in markets for products with limited substitution options and high values of lost load, e.g. in energy markets, taking such a risk could be costly. Therefore, a practicable option to mitigate market power is to incentivize the entry of new suppliers instead of taking direct actions against the dominant supplier.

[10] In principle, competitively priced pipeline gas could have been incentivized in Lithuania instead of LNG. However, Gazprom had also a dominant position in the markets of the neighboring Poland and Latvia leading to comparably high gas prices in those countries (European Commission, 2014).

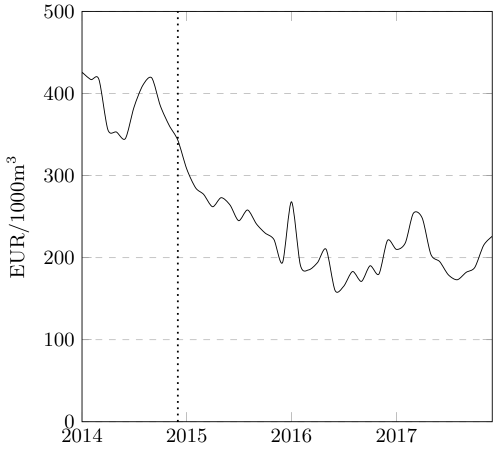

Figure 2.6.: Historical development of the Lithuanian weighted average import gas price

Source: Lithuanian National Commission for Energy Control and Prices (2017); vertical dotted line in December 2014 illustrates when the Lithuanian LNG terminal came online

As can be seen in Figure 2.6, gas prices in Lithuania decreased indeed significantly in 2015 and 2016 compared to 2014. In 2015, the LTC for LNG was binding, whereas Lithuania imported more than the contracted volumes in 2016. It would be interesting to test empirically the theoretical prediction that a binding LTC led to a higher adjusted consumer surplus in Lithuania in 2015 compared to a counterfactual situation without a minimum import quota. However, a development parallel to the commencing LNG imports was the decrease in global oil prices. Because Russian LTCs in Europe were still coupled to oil prices, this led generally to a lower level of Russian LTC prices (European Commission, 2015). Hence, even in the absence of LNG supplies, Russia may not have been able to enforce a monopoly price in 2015 and 2016 due to its contractual obligations. Additionally, because of substitution effects between natural gas and biofuels (Pakalkaité, 2016), the structure of the demand function for natural gas could have changed after 2014. Hence, empirically disentangling the different price decreasing effects in the Lithuanian gas market after 2014 is left for further research.

2.5. Conclusion

This analysis explains the economic rationale to incentivize the import of LNG in isolated gas markets like Lithuania by a minimum import quota. Before building the LNG terminal, Russia had a monopoly for natural gas in Lithuania, which led to high gas prices. In such a situation, supplier diversification can increase the national welfare due to a decrease in prices. If the price of LNG available at the global market is in the range of the marginal supply costs of the dominant supplier, the profitability of the LNG terminal can be ensured without market intervention. The analysis at hand, however, focuses on a situation in which the fringe volumes have higher marginal supply costs compared to the dominant supplier leading to a situation in which the dominant supplier can still exercise market power despite the existence of alternative supplies. It is shown that a minimum volume quota for the high-cost fringe leads to an increase in the consumer surplus adjusted by a compensation paid to the fringe firms. For a specific market situation, an optimal quota, from the point of view of the importing country, can be found. As a policy implication, countries with gas markets with dominant suppliers other than Lithuania could also consider to incentivize the import of competitively priced gas, ideally with flexible volume quotas.

3. Turkey's role in natural gas – Becoming a transit country?

This chapter analyses the possible future role that Turkey can play in European natural gas markets. The global gas market equilibrium model COLUMBUS is employed to assess the outcomes of different scenarios concerning natural gas supply routes to Europe through Turkey up to 2030. The results imply simply that under current conditions leading to low prices, i.e., tendency of European market to move towards a competitive environment, Turkey's role would be of only minor importance. In accordance with various scenarios presented in this chapter, Turkey's role is seen at its most important if European future demand is more than the projected and if the movement of European gas markets towards a competitive environment breaks down.

3.1. Introduction

Turkey's long-lasting ambition to become a natural gas transit country, if not a hub, has been motivated by the country's unique geographical location as a natural bridge between major gas producers in the Caspian, Middle Eastern and Russian regions and one of the major consumers, Europe. Turkey's importance and the likelihood of her being a transit country have remained relatively high during the periods of possible threats to sustainable natural gas supplies to Europe. To date continental Europe is one of the largest natural gas consuming regions in the world. According to BP (2014), after increasing from 338.1 billion cubic meters (bcm, hereafter) in 1991, annual natural gas consumption in the European Union 28 (EU, hereafter) peaked with 502.2 bcm in 2010. Although there has been a slight decrease since then, the International Energy Agency's (IEA, hereafter) 2015 World Energy Outlook (WEO 2015, hereafter) New Policies Scenario estimates that natural gas demand in Europe will increase by an annual compound rate of 0.7% reaching 610 bcm by 2040 (IEA (2015a)). Most of this demand will be met by imports, as has so far been the case. Indeed, European import dependency is expected to grow even more rapidly due to declining local production in countries such as the Netherlands and the UK.[1] WEO 2015 also suggests that Russia will continue to be the major source of natural gas supplies to Europe.

The issue of import dependency, especially on Russia, and its implications for European energy security has been widely discussed by academia and policy makers.[2] With the 2009 Russian-Ukrainian dispute over gas prices, import diversity emerged as an increasingly important item on the European policy makers' agenda. The Crimean crisis, which began five years later and was followed by disruptions in gas supplies over Ukraine and western sanctions against Russian companies and individuals, reactivated the issue of European natural gas supply security and import route diversity. In 2013, almost 50% of all gas imports from Russia passed through Ukraine (Martinez et al. (2015)). This constituted nearly 15% of total gas imports to the EU for the same year.[3] Annexation of the Crimean peninsula by Russia along with an already existing Russian-Ukrainian gas price dispute increased the fears of disruptions to EU gas supplies.

A vast amount of literature has evaluated the consequences of the Russian-Ukrainian crises in 2009 and 2014 both qualitatively and quantitatively.[4] Among the qualitative contributions, Pirani et al. (2009), for instance, emphasised that concerns about the reliability of Russian supplies as well as the Ukrainian transit route have increased among European policy makers as a result of the 2009 crisis. Chyong and Hobbs (2014) argued that European countries should engage more in reforming the Ukrainian gas sector rather than trying to restrict Russia's aim of using natural gas as a political weapon or for leverage. In addition, more recently Stulberg (2015) stated that the Russian strategy to use gas for political leverage failed due to significant changes in global energy markets. There also exist a number of articles that have tried to quantify the effects of Russian disruptions using various scenario analyses/modelling techniques. For instance, Lochner (2011c) simulated the 2009 Russian-Ukrainian crisis and found out that threats to European supply secu-

[1]According to the report share of imports in annual natural gas demand of European Union will increase from the current level of nearly 65% to 81% by 2040 IEA (2015a).

[2]See for instance, Correljé and van der Linde (2006); Mañé-Estrada (2006); Costantini et al. (2007); Reymond (2007); Spanjer (2007); Weisser (2007); Finon and Locatelli (2008); Remme et al. (2008); Sagen and Tsygankova (2008); Bilgin (2009); Hedenus et al. (2010); Monforti and Szikszai (2010); Söderbergh et al. (2010); Umbach (2010); Bilgin (2011a,b); Boussena and Locatelli (2013); Growitsch et al. (2014); Flouri et al. (2015); Hecking et al. (2016).

[3]Please note that the crisis in 2014 led to a significant decrease in these shares.

[4]See, for instance, Pirani et al. (2009), Abada and Massol (2011), Bilgin (2011b), Roth (2011), Belyi (2012), Balmaceda (2013), Behrens and Wieczorkiewicz (2014), Chyong (2014), Hecking (2014), Holz et al. (2014), Pirani (2014), Pirani et al. (2014), Richter and Holz (2014), Zachmann (2014), Martinez et al. (2015), Stulberg (2015).

rity were mitigated thanks to significant storage volumes. Moreover, Hecking et al. (2014) consider that Russian gas supply disruption, which continued for at least six months, would have profound effects on European gas security and that nine months of disruption could possibly cause a 46 bcm deficit in total European supplies. More recently, Martinez et al. (2015) provided a comprehensive assessment of the Russo-Ukraine crises and argued that the 2014 crisis did not impact too much on North Western European markets, thanks mostly to the Nord Stream pipeline which was built after 2009 crisis. However, the authors also stress that Southern and Eastern European countries are still vulnerable to any supply disruptions over the Ukraine transit route.

Under these circumstances, Turkey has been referred to as the most plausible alternative route for carrying Russian gas resources to Southern and South-eastern Europe. The Crimean Annexation followed by EU sanctions and doubts over cancellation of the Nord Stream pipeline expansion led to a major policy change on the Russian side, i.e. cancellation of the South Stream project and initiation of the TurkStream project in December 2014.[5] This was a significant turning point for Turkey in terms of becoming an essential player in the global gas market. Turkey's role was expected to increase not only due to the TurkStream project but also new supplies from Iran, the Kurdistan region of Iraq and the Eastern Mediterranean offshore fields, coming online in global gas markets for the first time. There has been a vast amount of literature on Turkey's possible role for European energy supply security and on her future as an energy transit country or hub.[6] Erdogdu (2010), for instance, analyses the European dependency on Russian gas and points out the possible positive implications of the once planned Nabucco project for European supply security. According to the author, Turkey occupies a significant geographic position in this respect, yet the availability of gas resources, which would have fed the Nabucco pipeline, was the determining factor for Turkey's role. Bilgin (2011a), moreover, suggests that Turkey's importance would increase until 2020 if and only if all European Union member countries adhere to a common energy security, as defined by the EU Commission, and diversify their import sources accordingly. Wigen

[5] On November 24, 2015 a Russian bomber aircraft was shot down by Turkish jets near the Syrian–Turkish border due to a claimed invasion of the Turkish territories. This was followed by increasing tension between the two countries and unilateral suspension of the project by Russian side. Yet, then in July 2016, governmental officials from both countries announced that relations would be back to normal in the short-term and that the project is put back on table. This volatile state of the relationship between Russia and Turkey sparks up the debate on Turkey's possible future as a natural gas hub and her role in European gas supply security.

[6] See for instance, Fink (2006), Barysch (2007), Bilgin (2007), Babal (2009), Saivetz (2009), Bilgin (2010), Erdogdu (2010), Roberts (2010), Wigen (2012), Winrow (2013), Yeni (2013), Cohen (2014), Demiryol (2014), Erdogdu (2014), Karbuz (2014), Tagliapietra (2014a).

(2012) similarly suggests that, although Turkey's geographical location offers her a unique opportunity for the future, realisation of this would depend very much on political developments in the region and the EU. According to Winrow (2013), becoming a major gas transit state is of secondary importance for Turkey's government, behind the need to safeguard its own energy security. Yet, the author stresses that Turkey would become an important component of the Southern Gas Corridor (SGC, hereafter) provided that sufficient gas supplies from northern Iraq, Turkmenistan and Azerbaijan are available. After a comprehensive analysis, Tagliapietra (2014a) concludes that Turkey was very unlikely to become a natural gas hub until 2025, yet she could play an important role if SGC infrastructure projects are realised and if European demand is high enough. Moreover, Tagliapietra (2014a) stressed that the 2014 Russo-Ukrainian crisis could be an important turning point in EU-Turkey energy relations as the crisis might rekindle debate on the issue of gas import diversity among European policy-makers.

Although there are many qualitative contributions, the literature so far fails to deal with how the recent disputes would quantitatively reshape Turkey's role in European gas supply security. Indeed, we are aware of only one quantitative analysis about Turkey's role, that of Lise et al. (2008), which focuses on gas corridors affecting the European natural gas market. The authors suggest that Turkey is in a favourable position to become an important natural gas transit country and that according to their 'Business-as-usual' scenario there would be 31 bcm of gas transited via Turkey to Europe by 2030. Yet, the study is quite outdated, considering the recent developments in international politics and energy markets, e.g., Russian–Ukrainian and Russian–Turkish crises, the lifting of Iranian sanctions, capacity expansions in northern Iraqi gas fields. The main contribution of this chapter is, therefore, to quantitatively show Turkey's changing role in the light of recent developments. A necessary and sufficient condition to become a transit country is to have significant amounts of gas flows over the borders. Yet, it takes a lot more than that to turn a country into a hub (Berk et al. (2017)). Hence, apart from the discussions on whether Turkey would become a gas hub for the European market, the main objective of the chapter at hand is to assess its potential role as a major transit country by quantifying the future east-west natural gas flows over the country. For this purpose, we use a global gas market simulation model, COLUMBUS, in accordance with Hecking and Panke (2012). Our methodology follows a two-fold structure.[7] Firstly, we used the COLUMBUS model to simulate a reference scenario, which is based on current global gas market conditions, over the period until 2030. To this end, we calibrated the model with the

[7] Please refer to Section 3.2 for details.

most recent data and in accordance with recent global gas market developments, such as the US shale gas revolution, decreasing fossil fuel prices and the European gas market's tendency to move to a competitive structure. Using this reference scenario, we measured future gas volumes that are supposed to flow through Turkey to European markets from different sources up to 2030. According to our results, gas volumes, mostly from Azerbaijan and Iran, transported over Turkey will reach 23.3 bcm/year, which constitutes 4.8% of total European demand, by 2030. Compared with the current situation this result suggests that Turkey's future role in natural gas would be enhanced only slightly.

Secondly, we analysed different scenarios, suggesting various drivers that may increase Turkey's importance in terms of transit volumes, for instance, higher than expected European demand, high Iranian production capacity or a European gas market that is characterised by oligopolistic gas suppliers all of which could change Turkey's role. The scenario in which there is higher than expected European demand and an oligopolistic European upstream gas market, to which Russia and its competitors exert market power, indicates the most important role for Turkey. According to this scenario, by 2030 Turkey's annual re-exports will reach 37.5 bcm, 6.8% of Europe's estimated annual demand. Conversely, given current market dynamics, low gas prices resulting from a competitive environment in the European gas market, there is quite a low possibility that the circumstances assumed by this scenario would exist in the period until 2030.

The structure of this chapter is as follows. Section 3.2 briefly introduces the methodology we have employed. Section 3.3.1 provides detailed results of the reference scenario. Different drivers that could enhance Turkey's future role as a natural gas transit country are featured in Section 3.3.2. Finally, Section 3.4 concludes with policy implications

3.2. Methodology

The quantitative analyses conducted in this chapter are based on the application of an economic model simulating the global gas market. This section provides the methodological setup including a brief description of the model used (Section 3.2.1)[8], data employed and assumptions made (Section 3.2.2). We also included the economic intuition behind the current developments in the global and European

[8] In this section we provide a brief description of the model. Please refer to the Appendix for the complete mathematical representation of the model.

natural gas market structure together with the implications for the model (Section 3.2.3). indices in an ex-post analysis.

3.2.1. Brief Description of the Model

We employ COLUMBUS, a global gas market model, developed Hecking and Panke (2012).[9] COLUMBUS is an inter-temporal partial equilibrium simulation model, which can derive possible gas market developments up to 2040, using 2014 data for the in-sample calibration process.[10] Although worldwide interdependencies are taken into account, special focus in this chapter is given to the European gas market. The model considers various aspects of the global gas market: production, consumption, storage, pipelines and LNG infrastructures. The spatial structure of the model is formulated in accordance with network-flow. Production and demand regions are represented by initial and final nodes, whereas liquefaction, re-gasification and storage terminals are represented by intermediate nodes.[11] The nodes are connected by arcs, which represent pipelines and LNG routes. The model takes several parameters regarding production, demand and transportation as exogenous inputs. These are capacities in production and transportation infrastructure, price elastic demand function as well as cost for investments or transportation. Furthermore, it reveals key outputs, such as production, trade flows, demand for investment into production and transportation infrastructure as well as equilibrium prices among the modelled gas markets.

COLUMBUS considers different market participants such as natural gas producers, exporters, LNG facility or storage operators, each trying to maximise profit simultaneously. Each individual actor tries to maximise its profit at each instant of time by having the ability to decide instantaneously on the production quantity at each production node, the supply quantity to each demand node, as well as the amount of investment in production, pipeline, LNG and storage facilities. Each agent's profit maximisation is subject to several constraints, such as production capacity, pipeline

[9]COLUMBUS model is developed at the Institute of Energy Economics (EWI) at the University of Cologne by Hecking and Panke (2012). Moreover, although we are aware of different gas market models such as that of Egging et al. (2008), Lise et al. (2008), Dieckhöner (2012) the reasoning for choosing COLUMBUS is that it accounts for several investment decisions, including infrastructure and production, and a more detailed European infrastructure.

[10]Although in principle model is available for simulating the gas markets until 2040, we restricted our attention until 2030 due to data availability.

[11]All nodes that are included in the model are presented in Appendix B.

transportation, storage, liquefaction and re-gasification as well as node flow and demand balances.[12]

Exporters are the key agents, who create trading connections between production and demand nodes whilst competing against each other and being able to exert market power in demand nodes. The model is designed as a mixed complementarity programming (MCP) problem similar to that of Egging et al. (2010), which allows the simulation of the strategic behaviour among individual natural gas exporters, acting as Cournot players, with different degrees of market power in different demand nodes. In accordance with Perry (1982) and Egging et al. (2008), the market power is controlled by a conjectural variation parameter varying between 0 and 1, indicating the degree of market power. As suggested by the equation B.1 in the Appendix, if conjectural variation is 0, the exporter is treated as a competitive supplier in the corresponding demand node.

Among the model's outputs, gas trade flows over capacity constrained pipeline or LNG routes carried out by individual exporters (determined by the maximization problem in equation B.1 and B.3). Investments in the existing capacity and into the new infrastructures (determined by maximization problems in equations B.8, B.12, B.14, B.15 and B.16) are of significant importance given the research question being addressed by this chapter. Taking the costs of production, transportation and investments exogenously, the model endogenously decides how much natural gas would be produced at each production node and the flow amounts from production to demand nodes. Therefore, the model also decides about the need of additional infrastructure capacity in order to realize the resulting gas flows between the production and demand regions.

3.2.2. Data and Assumptions

Demand is modelled on country level, assuming linear price elastic demand function. Data on price elasticity, reference demand and reference price are exogenously given to the model in order to estimate the demand function using the approach proposed by Lise et al. (2008). A country's demand, thereby, is divided into two sector groups: (1) households and miscellaneous and (2) industry and power generation. Moreover, the model also assumes that demand price elasticity is varying

[12]Please refer to the equations B.1–B.35 in the Appendix for the maximization problems of each player as well as the constraints and first order conditions.

over different countries as well as different sectors within a country.[13] For instance, while the industry has partly intermittent processes that will reduce natural gas demand when prices are high, household demand depends on heating behaviour not changing critically in the short term. Hence, the industrial sector is assumed to have a higher price elasticity of demand than the household sector (Growitsch et al., 2014). The main sources for the demand data employed in the model are the World Energy Outlook 2014 (IEA, 2015a), Natural Gas Information 2014 (IEA (2015b)), the Medium Term Gas Market Report 2014 (IEA (2015b)) and the Ten Year Network Development Plan 2015 (ENTSOG (2015)). All in all, the model considers 86 demand nodes; i.e. countries or country groups and covers over 95% of global gas consumption in 2014, which is the year of data calibration.

While demand data is exogenously provided[14], the model endogenously determines the respective production and supply decisions for each producer and exporter. Each exporter has control over at least one production node and each of these nodes face a capacity constraint at each point in time. The model includes 52 natural gas production nodes each including several gas fields, which accounts for over 95% of global gas supply. Historical production volumes, which are taken from Natural Gas Information 2015 (IEA (2015b)), are used as the exogenous production capacity of each production node at the corresponding year in order to calibrate the model. Moreover, the model chooses future production quantities and investment decisions, which would increase the production capacity, that maximise each agent's profit. Hence, each production node is subjected to a dynamic capacity constraint, which is endogenously determined by the production rate and investment into the capacity at corresponding year (equations B.9-B.11). Sources of the data on production parameters includes the WEO 2015 (IEA (2015b)), the Medium Term Gas Market Report 2015 (IEA (2015a)) and the Ten Year Network Development Plan 2015 (ENTSOG (2015)) as well as individual countries' corresponding statistical agencies.

Given its importance for the global gas market, the model covers a comprehensive data set on pipeline, LNG and gas storage infrastructure as well as long-term contracts (LTCs) between different countries. While infrastructure, either existing

[13] Although a general price elasticity of demand is assumed for every demand node and sector, after the in-sample calibration process the individual elasticities for demand nodes and sectors are redefined (see Lise et al. (2008)).

[14] Please note that the general level of demand development is an input to the model. However, since the COLUMBUS model is an equilibrium model, the equilibrium consumption is an output of the model and can deviate slightly from the input path. It is driven by price elasticities that are employed in the demand function.

or under development[15], is exogenously given, the model is able to invest endogenously into new infrastructure, as mentioned above. Data on existing pipelines were collected from the Ten Year Network Development Plan 2015 (ENTSOG (2015)), on LNG infrastructure were gathered from the Retail LNG Handbook 2015 published by the International Group of Liquefied Natural Gas Importers (GIIGNL (2015)) and from publications of Gas Infrastructure Europe (GIE and ENTSOG (2016)). Reports of Gas Storage Europe (GIE (2015)) and the Natural Gas Information 2015 (IEA (2015b)) served as the main data sources for gas storage facilities.

Finally, a detailed database on LTCs was developed using different sources, such as the literature survey by Neumann et al. (2015) and publications from the International Group of Liquefied Natural Gas Importers (GIIGNL). The model distinguishes different LTCs with take-or-pay (TOP) quantity or annual contracted quantity (ACQ). LTCs are exogenously given to the model as either existing or contracted volumes. As represented in equation B.35 LTC volumes are included in the market clearing constraint hence the amount of gas received by a demand node via LTCs is reduced from the demand to find the amount of gas needed to be supplied to that specific demand node. Hence, future traded volumes between two nodes include already existing or contracted LTC volumes. Moreover, since LTCs are purely exogenous, we did not control for negotiation processes.

3.2.3. Market Structure in European Gas Market: Oligopoly vs. Competitive

There seems to be consensus in energy economics literature that the upstream sector of the global natural gas market (Growitsch et al. (2014)), and in particular the European market (Mathiesen et al. (1987)), has always been best represented by an asymmetric Cournot oligopoly with a competitive fringe. Market imperfection was attributed to the high import dependency of European countries on a small number of exporters, e.g., Russia, Norway, the Netherlands and Algeria to some certain extent (Abada et al. (2013)). Russia, in particular, is recognised as the major supplier, which can exert certain market power to European, specifically eastern European, countries. Therefore, following the literature, we have constructed our model such that main suppliers, e.g., Russia, Norway, Netherlands and Algeria, can exert market power on European gas markets while others behave competitively, which creates an oligopoly with competitive fringe market structure.

[15] As well as projects with financial investment decision (FID) status based on ENTSOG (2015).

Yet, in the aftermath of the 2008/09 global economic crisis, there have been remarkable changes in the European gas market's structure. Increasing energy efficiency and the transition to renewable energy sources, thanks to high fossil fuel prices during the period between 2000 and 2008, followed by economic stagnation resulting from the crisis put downward pressure on gas demand growth in Europe. This might have already threatened Russia's position and power in the European gas market. Furthermore, the American shale gas revolution over the last years would further reduce European dependence on Russian gas through two channels. Firstly, expansion in US shale gas capacity drove Henry Hub gas prices down increasing the competitiveness of gas in the US power sector, which in turn led to huge amounts of US coal being available for export. As a result, worldwide coal prices decreased making coal even more competitive in the European power sector, which further reduced gas demand. Secondly, as the US moved from being a major importer to an exporter or at least self-sufficient consumer, global LNG overcapacities start to be redirected towards European markets.

All of these developments have driven and may further drive European gas prices down, especially in the spot market. Along with low oil prices since mid-2014, this threatened the future of long-lasting oil indexation pricing and long-term contracts, as consumers started to move towards spot LNG purchases.[16] As correctly noted by Henderson and Mitrova (2015), the most important implication of these developments is that the European market is moving to a competitive structure. Russia would have a tendency to hold gas prices low, both for contracted and future volumes, in order to maintain her share in the European market and to compete with the LNG spot market. Due to these recent developments, we assume that the European gas market will become competitive. Hence, in our reference scenario we have adjusted the conjectural variation parameter for the Cournot suppliers of Europe such that Russia and its competitors act competitively and hence exerting less market power compared to the pre-2014 European market. A different scenario entitled "Higher European Demand & Oligopolistic European Market" later relaxes this assumption.

[16] Please Stern (2009) on a comprehensive analyses of oil-indexed pricing and LTCs in European gas market.

3.3. Results

3.3.1. Reference Scenario Results

The reference scenario of this chapter is based on projections made by the New Policies Scenario of WEO 2015 of IEA (2015a) and is built to capture current conditions in the global gas market, as explained in Section 3.2.3. Given our chapter's objective, this section provides certain gas market projections regarding Turkey. Figure 3.1, for instance, represents Turkey's natural gas consumption from 1985 until 2014 (solid line) and the model forecast until 2030 (dotted line). According to the model Turkey's annual consumption will rise from 48.5 bcm in 2014 to 65.5 bcm in 2023. In accordance with WEO 2015, the annual growth rate of demand will decline after 2023 yet the demand will still reach 67.2 bcm by 2030.

There have been a number of studies forecasting Turkey's gas demand, including those from state institutions as well as from academia.[17] For instance, BOTAŞ, the Turkish national pipeline grid operator, estimated in 2008 that the country's natural gas demand will increase to 76.4 bcm by 2030 (BOTAS, 2008). Melikoglu (2013), moreover, using two different models estimated that demand will rise to 76.8 bcm (linear model) or 83.8 bcm (logistic model) by 2030. More recently, Ozdemir et al. (2016) forecasted that Turkey's annual natural gas consumption will increase to around 89 bcm in a high economic performance scenario and to around 56 bcm in a low economic performance scenario.[18] The fact that our model estimated lower natural gas demand than the previous estimates can be attributed to the recent contraction in Turkish economy.

Given that Turkey has low indigenous production and is, therefore, highly dependent on imported natural gas, it is worthwhile analysing the model's forecast about which natural gas source countries would supply the Turkish market (Table 3.1). There are currently five main sources that import natural gas into Turkey, namely the Russian Federation, Azerbaijan, Iran, Nigeria and Algeria (BOTAS, 2014). In 2014, for instance, 98% of Turkey's 49.8 bcm of natural gas consumption was imported from these five source countries with the following shares: Russia 56%, Iran

[17]Please refer to Melikoglu (2013) for a comprehensive literature review on natural gas consumption forecasts in Turkey.

[18]The authors provided the forecasted figures in million tonnes of oil equilvalent (mtoe) unit. Their forecasted volumes for high economic performance is 80 mtoe and for low economic performance is 50 mtoe. According to the BP Statistical Review of World Energy 2016 the approximate conversion factors, 1 million toe of natural gas is around 1.11 bcm. Hence, 80 mtoe and 50 mtoe can be calculated as 88.8 bcm and 55.5 bcm, respectively (BP, 2016).

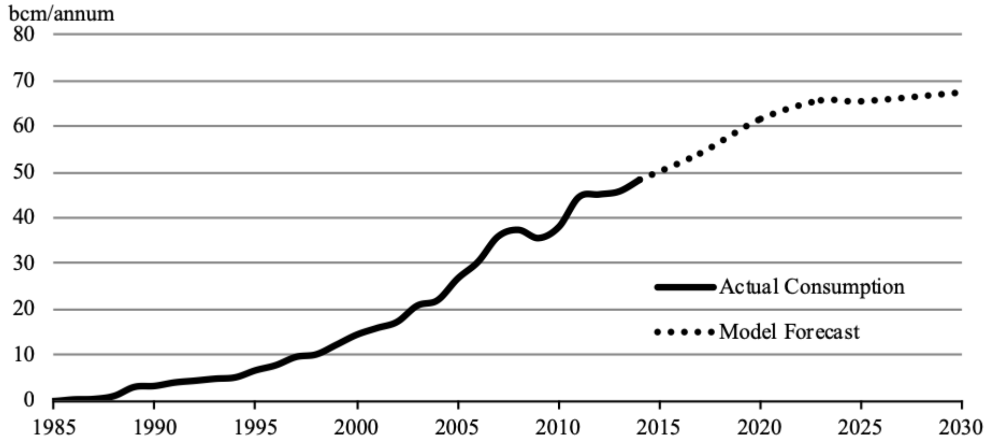

Figure 3.1.: Turkey's Natural Gas Consumption 1985-2015 and COLUMBUS' forecast until 2035

Data: Historical consumption data between 1985-2010 BP (2014), model calibration data between 2010-2014 from WEO 2015 of EIA (2015) and 2015-2035 model forecast.

19%, Azerbaijan 9%, Algeria 9% and Nigeria 7% (TPAO, 2014). The reference scenario, moreover, estimates that in 2017 out of these sources Russia would stay as the major exporter to Turkey by supplying 31 bcm of natural gas. The following three import sources would be Iran (9.7 bcm), Azerbaijan (8.3 bcm) as well as LNG imports from Nigeria and Algeria together with spot market purchases (a total of 5.1 bcm). According to the reference scenario, the composition of import diversity would alter significantly throughout the next 15 years. For instance, although Russia stays as the major source for Turkey with 35.3 bcm in 2030, her share of total imports will decline to 38.9% while that of Azerbaijan will increase dramatically to 34.8% (31.5 bcm).[19] By 2030 the third largest supplier would be Iran with 10.2 bcm, comprising 11.3% of total imports. The reference scenario also estimates slight increases in Iraqi and LNG imports over time.

According to Table 3.1, Turkey's total imports, including existing and contracted LTCs, will rise from around 54.1 bcm in 2017 to 90.5 bcm in 2030. Yet these volumes are not only for Turkey's own demand, which is supposed to increase to 67.2 bcm by 2030, but they also include re-exports from Turkey to Greece and Bulgaria (Table 3.1). According to the reference scenario, by 2030 there will be around 23.3

[19]Please note that these volumes are not only already existing long-term contracts (LTC, hereafter) but they also include estimates for future volumes. Future estimated volumes can either be LTC or spot trading. Note also that already existing LTC's have certain due dates. For instance in 2015 Turkey would import around 48 bcm gas due to existing LTC contracts, yet this volume will be only around 14 bcm in 2030. The remainder is to be imported using either new LTCs or the spot market.

bcm of gas re-exports from Turkey to Europe (9.2 bcm via Bulgaria and 14.1 bcm via Greece). This amount corresponds to around 4.8% of total European gas consumption, which is estimated by the model to be around 490 bcm by 2030.[20] From 2020 onwards according to the model Turkey will start to contribute more than 2.5% of European gas supplies. Although these shares correspond to a very small volume of gas compared with the current situation, this would enhance Turkey's role in Europe's gas supply security. In particular, Caspian natural gas sources that flow through Turkey would make a contribution to South-Eastern European markets, which are still characterised by a strong import dependency on Russian gas.

The in and out-flows presented in table 3.1 will be made possible only with a certain infrastructure, especially pipelines, and investment. One of the most important contributions made by the COLUMBUS model is that it estimates the annual demand for additional pipeline capacities between countries. According to the reference scenario, by 2030 there will be a total of 58 bcm additional capacity from the natural gas infrastructure network connecting Turkey to different countries (Table 3.2). The largest estimated pipeline capacity additions are: the Georgia–Turkey pipeline, carrying Azerbaijani and Turkmen gas, with a total capacity addition of 20.1 bcm, which can be attributed to a capacity addition to TAP/TANAP pipeline, the Russia–Turkey pipeline with a total capacity addition of 19.7 bcm and the Turkey–Bulgaria pipeline with a total capacity addition of 9.3 bcm.

Out of these, the Russia–Turkey pipeline investment is of significant importance. This 19.7 bcm of additional capacity can easily be attributed to the TurkStream project, with the pipeline planned to have a capacity of 31.5 bcm/year, 14 bcm of which is intended to feed Turkey's own demand with the rest being re-exported to Europe.[21] Hence, given that Turkey's own consumption would increase to 6 bcm by 2030, according to the reference scenario the TurkStream project would serve only Turkey's own needs and would not contribute to its ambition to become a gas transit country. Indeed, this can be directly concluded by looking at the inflows provided on Table 3.1. The model estimates that there would be no gas flows from Bulgaria; hence the pipeline with 19.7 bcm of capacity would be built in order to offset the transit volumes from Russia to Turkey through Ukraine and Bulgaria. Furthermore, instead of transiting natural gas via Turkey, Russia would invest in an additional

[20]Here, European consumption refers to the total amount of projected consumption in European continent, excluding Turkey. Countries included are Austria, the Baltic countries, Belgium, Bulgaria, Switzerland, the Czech Republic, Germany, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Moldova, the Netherlands, Norway, Poland, Portugal, Rumania, Sweden, Slovenia, Slovakia, the United Kingdom, Yugoslavia

[21]`http://turkstream.info`. Access date: 30.09.2016

Table 3.1.: Turkish Gas Flow Balance Including Already Existing and Contracted LTCs by Source Country (all figures in bcm)

	2017	2020	2023	2025	2030
From Russia (through the Black Sea)*	16.0	33.9	34.7	33.9	35.3
From Russia (through Bulgaria)**	15.0	0.1	2.0	0.0	0.0
From Azerbaijan (through Georgia)***	8.3	23.3	29.2	31.5	31.5
From Iran	9.7	6.3	5.0	7.4	10.2
From Iraq	0.0	1.2	0.2	0.0	4.1
From Israel	0.0	0.0	0.0	0.1	0.4
Total Pipeline Gas Imports	**49.0**	**64.8**	**71.2**	**72.8**	**81.5**
LNG from Algeria	2.4	2.4	2.4	0.0	0.0
LNG from Nigeria	1.1	1.1	0.0	0.0	0.0
LNG from Spot	1.6	5.5	6.9	9.4	9.0
Total LNG Imports	**5.1**	**9.0**	**9.3**	**9.4**	**9.0**
Total Gas Imports	**54.1**	**73.8**	**80.5**	**82.3**	**90.5**
Turkey's own Demand	**54.1**	**61.5**	**65.5**	**65.3**	**67.2**
To Bulgaria	0.0	1.6	3.3	4.6	9.2
To Greece	0.0	10.7	11.8	12.4	14.1
Total Gas Re-exports	**0.0**	**12.3**	**15.0**	**17.0**	**23.3**
Share of Gas Re-exports in Europe's consumption†	**0.0%**	**2.5%**	**3.1%**	**3.5%**	**4.8%**

Notes: Figures include contracted LTC's over Turkey, e.g. from Azerbaijan to Greece and further to Italy (TAP Project).
* We did not differentiate between TurkStream and Blue Stream since future volumes may be carried either by using already existing Blue Stream and by enhancing its capacity or by investing into new project, i.e. TurkStream.
** There are in principle other source countries that can feed Turkey through Bulgaria yet the model in the reference scenario estimates that the volumes that are transported from Bulgaria to Turkey will be Russian originated.
*** Azerbaijan LTCs involve 3 contracts to Turkey: Phase I and BIL, which are already operational and Phase II, which comes online in 2018 (Source: BOTAŞ Official Website).
† Total European gas consumption (projected) excluding Turkey (Countries: Austria, Baltic countries, Belgium, Bulgaria, Switzerland, the Czech Republic, Germany, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Moldova, the Netherlands, Norway, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia, the United Kingdom, Yugoslavia)

pipeline to run through the Black Sea directly to Bulgaria. The project, also known as South Stream[22], which has often been discussed in the past, would enable Russia to create a direct connection to the EU without passing through an additional transit country. However, in the reference scenario the model identifies a demand only for an additional capacity investment of 7 bcm/year. The official project capacity was planned to be 63 bcm/year.

Another important outcome of the model is that there would be 13.4 bcm/year of additional pipeline capacity investment from Turkey to Europe (Bulgaria and

[22]Project was cancelled in 2015 due to political reasons. However, due to the model not considering political assumptions and being purely based on economic rational, a direct investment via the Black Sea to Bulgaria is suggested.

Table 3.2.: Demand for Additional Pipeline Investments Connecting Turkey

bcm/year	2020	2023	2025	2030	Total
From Russia	18.3	0.5		0.9	19.7
From Iran				0.2	0.2
From Iraq	1.2			2.9	4.1
From Georgia*	11.7	6.0	2.3	0.1	20.1
From Israel			0.1	0.3	0.4
To Greece*	2.1		0.3	1.7	4.1
To Bulgaria	1.9	1.4	1.8	4.2	9.3

Notes: The numbers represent the demand for capacity additions under the corresponding year. Total amounts are the total added capacity between two countries from 2015 to 2030.
* The TANAP+TAP pipeline is not part of the investment decision because it is already under construction and given exogenously to the model

Greece) by 2030. This additional pipeline would carry mostly Azerbaijani and to some certain extent Iraqi gas to European markets.

In summary, the reference case scenario estimates that there would be significant increases in gas import volumes from Azerbaijan as well as the LNG spot market and Turkey's role in European gas supply security would slightly increase due to some of the imported volumes being directed as re-exports to Greece and Bulgaria. These results seem to be conceivable, given the vast natural gas resources existing in Azerbaijan and current developments in global gas markets leading to lower LNG prices, thereby increasing the competitive advantage of LNG over pipeline gas. Hence, the most important portion of imports will serve to meet the country's own demand. This result is also consistent with the agenda of Turkish policy-makers, whose priority is to secure adequate supplies for Turkey's internal market. In order for Turkey to become a reliable partner in European gas supply security, more gas volumes from the countries mentioned above or other sources, such as Iraq or Iran, must feed Turkey's re-export volumes. The reference scenario notably estimates that some Iraqi gas will start flowing across Turkish borders as early as 2020 and by 2030 its import volumes will increase slightly to 4.1 bcm/year, equivalent to Iraq's total export capacity by then.

What is unexpected about the results, though, is that although the sanctions are being lifted, there would be no significant increase in imports from Iran, which is supposed to be one of the major suppliers in the Southern Gas Corridor (Tagliapietra, 2014a). It is valuable, therefore, to shed more light on the economic intuitions behind the Iranian results and their implications for Turkey in its ambitions to become an important gas transit country. One of the main reasons for Iran's low export volumes to Turkey is to do with its own domestic consumption. In line with WEO 2015, the model estimates that Iran's annual natural gas consumption will grow gradually from the current level of around 170 bcm to around 250 bcm by 2030. This huge increase may be attributed to recent political developments, namely the lifting of sanctions, which will result in increasing Iranian economic activity. One other key source of demand for Iranian natural gas is the upstream oil industry. Due to the geological structure of petroleum reservoirs in the country, natural gas is re-injected into oil fields as an enhanced oil recovery technique. Hence, the country is also consuming considerable amount of natural gas in order to maintain its oil production (Moryadee, 2015, Stevens, 2015).

Indeed, to satisfy its own needs, the model further estimates that Iran would be importing more than 10 bcm of gas from Turkmenistan from year 2020 onwards. This amount more or less equates with the gas exports to Turkey. The model also estimates that starting from 2020 Iran would be exporting some volumes of gas to India via Pakistan (reaching around 11.7 bcm by 2030) to enjoy better market prices than would be available from the European market. According to the model, India's equilibrium market prices would be on average around 30% higher than Turkish prices until 2030. Moreover, although Iranian officials often refer to LNG as one other option for exporting the country's gas resources[23], the model's reference case scenario does not estimate significant increases in Iran's LNG export capacity. This may be attributed to prohibitively high sunk costs related to LNG infrastructure, i.e., liquefaction and re-gasification terminals, and already existing overcapacity in the global LNG market.

Although according to the model the economic importance of Iran will remain relatively low, Turkmenistan would rise as a major supplier, along with Azerbaijan, in the Southern Gas Corridor. The model estimates huge increases in Turkmenistan's annual production, from around 82 bcm in 2014 to 162 bcm in 2030. This enormous increase in the country's production can be attributed to the vast gas resources yet to be developed. According to the model Turkmenistan will start investing in an upstream gas industry starting from 2020 when the gas prices all over the world start to increase. The model estimates that there are two main export destinations for the Turkmen gas, Eastern Asia (India and China) and Turkey. In 2030 Turkmenistan will be sending over 50 bcm of natural gas to India and China via Pakistan through the TAPI[24] pipeline and Kazakhstan. There exists one route over which Turk-

[23] See for instance Natural Gas Europe (2015a,b,c).

[24] TAPI is the abbreviation for Turkmenistan-Afghanistan-Pakistan-India Pipeline. The pipeline is planned with a capacity of 33 bcm/a. The model suggests a demand for investment of 50 bcm/a. Thus, the planned capacity is undersized.

Figure 3.2.: Estimated Gas Flows through Turkey in 2030 – Reference Scenario

menistan can deliver gas to Turkey, which is via Azerbaijan and Georgia. By 2030 Turkmenistan will start delivering 7.2 bcm via Azerbaijan, for which the model further estimates that there will be a new pipeline connection between Turkmenistan and Azerbaijan with a capacity of 7.2 bcm/year. This pipeline can be attributed to the planned Trans-Caspian pipeline, whose capacity is estimated to be 30 bcm/year.[25]

3.3.2. Drivers for Turkey's potential to become transit country

The results of the reference scenario so far suggest that Turkey's importance as a transit route in European supply security will only slightly increase over the period under investigation. In 2030, for instance, Turkey would re-export 23.3 bcm of gas to Bulgaria and Greece, contributing only 4.8% of total European consumption, while her imports would rise to 90.5 bcm (Figure 3.2). Furthermore, according to the results these re-exported gas volumes would be originated mostly from Azerbaijan and Iran, while Russian gas will be consumed within the Turkish domestic market.

As aforementioned, the reference scenario is based on the fact that the current economic conditions within the global and European gas markets would sustain in the medium term. On the other hand, there could be some developments which could alter the role of Turkey compared to the reference scenario. In this section, we investigate under which conditions Turkey's role would increase and in doing so we

[25]The model is used here is an economic optimisation model hence does not adjust for political conditions. In the case of Trans-Caspian pipeline, although it is an economically viable project, it would be politically difficult to materialise due to the border conflicts between Caspian countries. Please see O'Lear (2004) and Madani et al. (2014) for further discussion on the Caspian dispute.

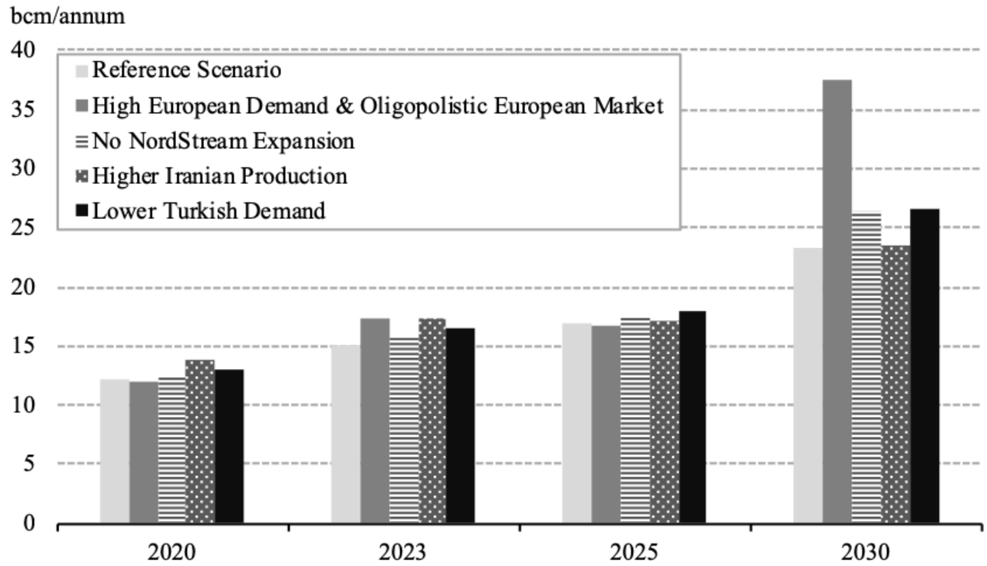

Figure 3.3.: Estimations of natural gas transportation over Turkey to Europe until 2030 under different scenarios

consider different scenarios, which allow us to detect drivers for higher natural gas transits via Turkey. Figure 3.3 represents the gas transportation amounts over Turkey to Europe until 2030 obtained by the simulations of five main scenarios, namely (1) Reference Scenario, (2) High European Demand & Oligopolistic European Market, (3) No Nord Stream Expansion, (4) High Iranian Production, and (5) Lower Turkish Demand.

As mentioned earlier, currently the European gas market is moving towards a competitive environment, due to the over-capacity of LNG directed to Europe instead of the US, thanks to the shale revolution, leading prices to decline. On the other hand, low gas prices may have profound positive effects on future expected demand. Furthermore, there are several other drivers that can generate higher European demand, as for instance a fuel switch in power markets due to the higher prices within the EU-ETS. Accordingly, we analysed to what extent an increase in European demand would affect Turkish gas transits by 2030.[26] Results reveal that there will be only 1.5 bcm/year of additional transits via Turkey compared with the reference scenario. The increase in European demand would, therefore, mostly be covered by LNG and increasing Russian supplies. Hence, the benefit to Turkey of an increased European demand is relatively minor.

[26]In this scenario, we assumed that European demand will be 20% more than the demand projected by the reference scenario. Please note that Turkey is also included in the European continent hence its demand is subjected to increases also by a further 20%.

Moreover, if gas prices stay relatively low in the medium term, US shale investment would decline leading the country to become an importer again. Consequently, a supply glut of LNG, based on global overcapacities which is expected to put Europe in a good position, would be over. Along with the demand increase this would increase Russian share in European gas supply and hence its market power in European gas markets, which would push the European market to an oligopolistic structure. We constructed a scenario, therefore, in which Russia and its main competitors act in an oligopolistic way to enforce higher prices. It can be shown that if this is the case, European demand for gas from the Southern Gas Corridor increases. The results of this scenario, in which we assume imperfect competition in European market along with strong European demand[27], illustrate that Turkey's re-exported gas volumes to Europe would increase significantly to 37.5 bcm/year, contributing almost 7% of the European gas demand by 2030. Provided that Russia is withholding production capacity due to its oligopolistic behaviour, most of this 37.5 bcm would be supplied by other countries: Azerbaijan (19 bcm), Iran (7.5 bcm), Turkmenistan (5 bcm) and Iraq (1.3 bcm). Compared with the 23.3 bcm/year in the reference scenario, this would indicate a greater likelihood for the Southern Gas Corridor to feed Turkey's ambitions of becoming an important natural gas transit country. Yet, the assumptions borne in these scenarios are not very likely to occur in the short-term given current conditions in global and European gas markets.

Furthermore, there has been much debate about the possible cancellation of a Nord Stream expansion due to various political issues between Russia and the EU, including the Crimean annexation and the Syrian dispute. Considering these issues, we considered a case where no expansion in the Nord Stream pipeline was assumed. The results of this scenario in comparison to the reference scenario, suggest that Russia would use already existing gas infrastructure in Ukraine to feed the demand shortage for Central and Western Europe. The simulation results suggest no demand for investment into an additional pipeline from Russia to Turkey and further to Europe (i.e., TurkStream). This illustrates that the potential pipeline projects Nord Stream 2 and TurkStream are not in competition with each other. Moreover, the results within this scenario show that there would be no significant change in the gas volumes that are transited through Turkey from other sources, namely Iran, Azerbaijan and Iraq.

In the next step we analysed the impact on global gas markets of lifting Iranian sanctions and in particular how Turkish gas transits would be affected. It is assumed,

[27] In this scenario, in addition to the 20% more demand, we adjusted the conjectural variation of main suppliers of Europe such that they have more market power than the reference scenario.

therefore, that Iranian production capacity is higher than in the reference scenario[28], thus allowing Iran to export higher volumes of gas. However, results show that Iranian exports to Europe via Turkey would increase only slightly up to 4.3 bcm by 2030, compared with 3.9 bcm in the reference scenario. Instead of exporting via new, high cost infrastructure in Turkey to the European market, Iran decides to invest in infrastructure to Pakistan and India. Due to stronger demand growth and, therefore, higher price signals, these countries are of greater interest to Iran. In total Turkish re-exports to Europe would increase only slightly by 0.3 bcm by 2030.

Finally, variations in Turkish demand[29] and their effects on Turkish transit volumes are analysed. It is easy to foresee an overall worsening of the Turkish economy in the future due to, for instance, internal political disputes, terrorist attacks and their implications on the tourism sector, together with depreciation of the Turkish lira against the US dollar and Euro.[30] Compared with the reference scenario, lower Turkish domestic demand would lead to additional re-exports to Europe of 3.4 bcm by 2030. Thus, the development of Turkish demand has only a small effect on the country's transit amounts. The reason is that Russia acts as a swing supplier to the Turkish market and Turkey's demand reduction is merely balanced out mainly by a reduction in Russian supplies. Because Russia prefers direct connections to Europe, for instance through South Stream, the change in Turkish transit volumes would be low.

3.4. Conclusion and Policy Implications

This chapter has aimed to assess quantitatively Turkey's future role for the European natural gas market. For this purpose we used COLUMBUS, a global gas market simulation model, to conduct several scenarios regarding Turkey. Results from our-reference scenario imply that Turkey's role would increase only slightly until 2030, by which time 23.3 bcm of natural gas, originating mostly from Azerbaijan, Turkmenistan and Iran, would flow across Turkish borders to European markets. Although these values are not high enough to conclude that Turkey could turn into an important natural gas transit country, according to the reference scenario Turkish

[28] It is assumed that Iranian production capacity is 20% higher, for instance due to higher foreign direct investment following the cessation of sanctions.

[29] It is assumed that Turkish projected demand would be 20% lower than in the reference scenario.

[30] Please see for instance: "Rough Seas Ahead for the Turkish Economy" In: Stratfor, 01.11.2016. Available at: `https://www.stratfor.com/analysis/rough-seas-ahead-turkish-economy` (Access date: 07.11.2016).

transits would at least contribute a positive effect to the natural gas supply diversity of South Eastern European countries which are highly dependent upon Russian gas.

Moreover, from various scenarios analysed the one assuming an oligopolistic market structure and stronger than expected demand in Europe would have the greatest impact in elevating the amount of gas flowing through Turkey to European continent. The results of this scenario suggest that by 2030 the amount of gas that could be re-exported from Turkey to European markets would reach 37.5 bcm, constituting 6.8% of total European demand. However, the assumptions made in this scenario are quite unlikely ever to be realised given the current conditions in global and European gas markets. The second scenario that creates a major deviation from the reference scenario features lower than expected Turkish gas demand growth due to a possible weakening of the Turkish economy. Accordingly, total re-exports would be 26.7 bcm, which is slightly higher than the reference scenario by 2030.

One of the most important outcomes of this chapter according to our simulation model is that Turkey's importance as a future European natural gas transit country would be rather limited and highly dependent on several internal and external factors such as the behaviour of Russia together with future Turkish and European demand. Out of these factors, European demand and the ability of major suppliers of Europe, particularly Russia, to exert market power are the most significant. Turkey's role may be stronger if European gas demand is higher than expected and Russia exerts greater market power. From a European perspective these conditions would not be preferable as they would lead to higher gas prices and a corresponding worsening in general welfare levels.

4. Natural Gas Transits and Market Power – The Case of Turkey

Turkey is a key country in order to realize the Southern Gas Corridor (SGC) due to its geographical location. However, as the main transit country within the SGC, Turkey could potentially exert market power with gas transits. Whether Turkey exerts market power or not, is crucial for an economic assessment of the SGC. Hence, the article investigates this issue quantitatively using a global partial equilibrium gas market model. An oligopolistic and a competitive supply structure in the European upstream market in 2030 are considered in the model based on calibrations to historical gas market situations. If the European gas market in 2030 is characterized by an oligopolistic supply, Turkey is able to exert market power resulting in higher prices compared to competitive transits, in particular in South Eastern Europe. In a competitive market structure, however, the importance of the SGC and thus the potential of Turkish transit market power is limited.

4.1. Introduction

The Southern Gas Corridor (SGC) consists of planned pipeline projects that connect the natural gas producers in the Caspian region and the Middle East (Azerbaijan, Turkmenistan, Iran, Iraq and Israel) with the natural gas markets of the European Union (EU). The EU promotes the SGC for two reasons: (1) it would like to diversify its natural gas supplies and (2) it aims to close its growing supply gap that arises due to decreasing indigenous production. Turkey has a key role in realizing the SGC, since Turkey's geographical location is between the producing countries and the EU. This crucial role of Turkey is widely discussed in the literature.[1] Compared to Ukraine, which is a single-source transit country for Russian gas only, Turkey has the potential to become a multi-source transit country fed by several suppliers from the Caspian region and the Middle East or Russia. The goal of the Turkish

[1] See for instance Berk et al. (2017), Tagliapietra (2014a), Tagliapietra (2014b), Winrow (2013), Wigen (2012) or Lise et al. (2008)

government, however, is not only to aim for a pure transit role for Turkey, i.e. allow upstream producers the access to the Turkish transmission network and to the EU downstream market, but rather to use its multi-source advantage for actively trading in the natural gas markets, as is outlined in Skalamera (2016):

> "Turkey, however, bargained hard against a straightforward transit role, intending instead to take over the role of a hub, which means that it would buy gas arriving at its borders, consume what it needs, and sell on the balance at profit."

However, this perception is far away from the economic definition of an energy hub.[2] In economic terms, the Turkish perception means that Turkey wishes to use its geographical location to exercise market power in the European natural gas market (transit market power). If the natural gas producers have market power themselves, Turkey's plans would give rise to double marginalization (Tirole, 1988). This perspective is missing within the current discussion about the SGC although it could potentially eliminate the economic benefits of the entire project.

Hence, the research objective of this chapter is to investigate possible implications of Turkey's strategic behavior for the EU natural gas markets and for the economic feasibility of the SGC project. The global natural gas market model COLUMBUS (Hecking and Panke, 2012) is extended and applied in order to simulate strategic behavior of transit countries like Turkey.[3] In a simulation for the year 2030, a case with Turkish market power is compared to competitive Turkish transits, i.e. a scenario in which upstream producers have to pay only transportation costs to ship gas through Turkey to European markets. Besides varying the Turkish behavior, different market structures in the European upstream market are considered, i.e. an oligopolistic upstream market and a competitive upstream market, in order to derive a comprehensive understanding of Turkey's role in the SGC.

The structure of the chapter is as follows: In Section 4.2, a review of literature that is is relevant for the analysis is given. A stylized theoretical model to discuss

[2] Heather (2015), for instance, identifies five important requirements for an energy hub: a high level of (1) liquidity, (2) volatility and (3) anonymity as well as (4) market transparency and (5) traded volumes. Furthermore, a physical hub is a location where several pipelines coming from and going to different directions converge and enable physical trade and competition. The Turkish perception of becoming a hub rarely fulfills those requirements. For a deeper discussion of this topic see also Berk et al. (2017).

[3] In reality, besides buying gas volumes upstream and reselling them downstream, a transit country could exert market power by inducing high transit fees or imposing taxes for gas transits on its territory. Those measures would result in a mark-up increasing the price of gas deliveries through the transit country and hence have a similar effect for the final customers as a policy of the transit country to explicitly buy and resell gas.

the problem of Turkish transits is developed in Section 4.3. Subsequently, in Section 4.4, the global natural gas market model COLUMBUS and its inputs are described. Afterwards, the model calibration is discussed. Based on the calibration, Section 4.5 focuses on the model results and discusses the implications of Turkish transit market power for the EU. Finally, Section 4.6 concludes.

4.2. Literature Review

There are four different streams of literature to which this work is related to: (a) literature about gas market modeling based on non-cooperative game theory, (b) literature about natural gas transits, (c) publications about Turkey's energy relations, and (d) literature focusing on double marginalization.

The first literature stream is based on simulation models that are programmed as mixed complementarity problems (MCP). As the COLUMBUS model that is used within this work, MCPs allow the simulation of market behaviour and thus to consider different forms of competition on different stages of the value chain. An early study is provided by Boots et al. (2004) in which gas producers are represented as oligopolists in a static model called GASTALE. The model considers downstream traders that act either oligopolistically or competitively. The study shows that successive oligopolies in gas markets lead to high prices - similar to the case of successive oligopolies in the SGC in this chapter. Later on, a dynamic version of GASTALE is developed by Lise and Hobbs (2009) that consider the SGC producers Azerbaijan, Iran and Iraq as potential suppliers for Europe. A further early work is Gabriel et al. (2005a). It also considers the natural gas supply chain as a MCP in which the traders marketing gas of the producers had market power. Several existence and uniqueness results are provided as well as illustrative numerical results. Gabriel et al. (2005b) considers more in-depth numerical simulation of a version of this model for the North American natural gas market. In a later contribution by Holz et al. (2008), a static model named GASMOD is applied to analyze the European gas markets with regard to their market structure. Using data of 2003 they analyze different combinations of competition in upstream and downstream markets and come to the conclusion that Cournot competition in both markets (double marginalization) is the most accurate representation to model the European gas market. In Section 4.4.3, a similar calibration exercise is done for the years 2014 and 2016. In later research, Holz (2009) extends the static GASMOD model into a dynamic version.

Within the stream of literature that focuses on gas transits, Yegorov and Wirl (2010) analyze games that appear in the context of gas transits. They distinguish between games with a transit country as a net gas exporter (such as the case of Turkem gas transits through Russia) and with a transit country as a net gas importer (such as Turkey). They conclude that the game structure arising from a transit problem is not absolute but depends on geography and international law. Furthermore, von Hirschhausen et al. (2005) analyze Ukrainian market power for Russian gas exports to Central Europe. They focus on the effects of an alternative Russian export route to Central Europe, the Yamal pipeline via Belarus and how cooperation between Ukraine and Russia could have made the investment into the Yamal pipeline unnecessary. Dieckhöner (2012) analyzes Ukrainian transits from a security of supply perspective discussing potential diversification options for Europe like the Nabucco pipeline. Later, Chyong and Hobbs (2014) introduce a strategic European natural gas market model to analyze a gas transit country. They apply their model to investigate the case of the South Stream gas pipeline. The question of Ukrainian transit market power is hereby important for the profitability of this offshore pipeline. Transit market power is represented by a conjectured transit demand curve approach. However, the conjectural variations of the transit country are chosen as a calibration parameter and vary between 0 and 1. This approach is common in natural gas market modeling but also often criticized, e.g. by Perry (1982), Dockner (1992) and Smeers (2008). Within the literature about transit problems, there are further cooperative game theory approaches: Hubert and Ikonnikova (2004), Hubert and Suleymanova (2008), and Hubert and Ikonnikova (2011), for instance, analyze market power of transit countries within the Eurasian supply chain. Furthermore, they examine strategic investments into alternative infrastructure projects to bypass the transit countries and reduce their market power. However, the above-mentioned works focus all on Ukraine, a single source transit country fed by Russian gas only. In the chapter at hand, the potential multi-source transit country Turkey that would not be dependent on a single dominant exporter is in the focus of investigation.

Within the literature about Turkey's energy relations, there are geopolitical and economic contributions. Cagaptay (2013) discusses geopolitical factors associated with different potential gas suppliers for Turkey. Skalamera (2016) finds that there are many obstacles for Turkey to become a gas hub. Furthermore, Berk and Schulte (2017) show that Turkey's potential to become an important transit country for the European natural gas market is strongly restricted. Moreover, they quantify different drivers that could increase Turkish transit volumes and therefore its importance as a transit country.

Apart from a specific gas market context, there are works that discuss options to avoid double marginalization. Joskow (2010) analyses different factors that impact the decision of companies to either rely on markets to source supplies or to integrate vertically. Double marginalization would be a neoclassical factor favoring vertical integration. In the context of this chapter, competitive access for upstream gas producers to the Turkish transmission grid would lead to the same shipment quantities through Turkey that vertically integrated companies, i.e. upstream producers owning pipelines through Turkey, would choose. Besides the neoclassical double marginalization approach, which focuses on the implications of market power for market efficiency, Joskow (2010) also mentions Transaction Cost Economics (TCE), which focuses on the implications of market power for firms' efficiency. According to TCE, firms could rely on different contractual relations that minimize other firms' bargaining power, e.g. vertical integration, joint ventures, long-term contracts. The conditions of those contractual relations depend on the degree of asset specific investments required for a given market and the extent to which firms are locked-into already binding contractual relations. In the context of this chapter, which has a market efficiency perspective, contractual relations could avoid a double marginalization structure and transfer a part of the upstream producers' rent to Turkey or European consumers. Therefore, it is important to note that the simulated configurations (competitive transits and double marginalization) are two extreme outcomes, and bargaining about the rents could also lead to a solution in between.

The value added to the literature of this analysis is two-fold. Firstly, it considers the specific case of Turkey and quantitatively examines its potential to exercise transit market power in the EU gas market. Secondly, a double marginalization approach (successive oligopolies) is used to describe a multi-source transit country like Turkey.[4]

4.3. Stylized Theoretical Model

Tirole (1988) describes double marginalization in the most basic setting, the succession of two monopolies in a vertical integrated value chain. In this section, an extended version of this textbook model is introduced to describe a market structure with a multi-source transit country potentially giving rise to double marginalization

[4]In contrast to Chyong and Hobbs (2014), the conjectural variation of a transit country takes on either the value of the Cournot conjecture or the competitive conjecture. Thus, the critique of arbitrary conjectural variations is not relevant for this analysis.

and suppliers that are not dependent on the transit country. Therefore, a setup with 4 players, 3 producers and the multi-source transit country, is considered in order to obtain insights into the functioning of transit market power. It is assumed that the transit country and the producers are not vertically integrated. Producer 1 can sell volumes q_1 directly to the final market representing a value chain without double marginalization. Producer 2 (respectively producer 3) is dependent on the transit country and thus can only sell volumes q_2 (respectively q_3) to the transit country that then resells the volumes $q_T = q_2 + q_3$ to the final market. Figure 4.1 illustrates the stylized model. The assumption that all the volumes entering the transit country are resold corresponds to the assumption that no domestic market of the transit country needs to be served (in the absence of indigenous production of the transit country).

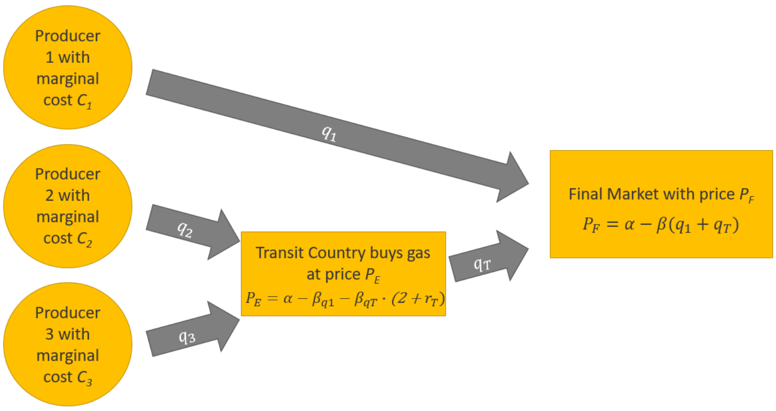

Figure 4.1.: Illustration of the stylized model

The final market has a price P_F and a total supply $Q = q_1 + q_T$. The inverse demand function of the final market is assumed to be linear with an intercept α and a slope β:

$$P_F(Q) = \alpha - \beta Q$$

The profit-maximization problem of producer 1 with her marginal cost C_1 is given by:

$$max(\Pi_{P1}) \text{ with } \Pi_{P1} = (P_F(Q) - C_1) \cdot q_1 \text{ subject to } q_1 \geq 0 \tag{4.1}$$

The corresponding first-order conditions with a conjectural variation $r_1 = \frac{\partial q_T}{\partial q_1}$, which takes on the value of 0 for Cournot behavior and -1 for competitive behavior of the producer, are:

$$C_1 - P_F + \beta \cdot (1 + r_1) \cdot q_1 \geq 0 \perp q_1 \geq 0 \tag{4.2}$$

Producer 2 (respectively producer 3) produces gas at marginal cost C_2 (respectively C_3) and sells it to the transit country at the price P_E. The problems of the producers 2 and 3 are given by:

$$max(\Pi_{Pi}) \text{ with } \Pi_{Pi} = (P_E(q_i) - C_i) \cdot q_i \text{ subject to } q_i \geq 0 \text{ for } i = 2,3 \tag{4.3}$$

The corresponding first-order conditions are:

$$C_i - P_E - \frac{\partial P_E}{\partial q_i} \cdot q_i \geq 0 \perp q_i \geq 0 \text{ for } i = 2,3 \tag{4.4}$$

The inverse demand function $P_E(q_T)$ is found by considering the transit country's profit maximizing problem and its first-order conditions with the conjectural variation $r_T = \frac{\partial q_1}{\partial q_T}$. The transit country's profit is determined by the difference between the price of the final market $P_F(Q)$ and the price for which the transit country can buy volumes from the upstream producer P_E:

$$max(\Pi_{TR}) \text{ with } \Pi_{TR} = (P_F(Q) - P_E) \cdot q_T \text{ subject to } q_T \geq 0 \tag{4.5}$$

The first-order conditions are given by:

$$P_E - \alpha + \beta q_1 + \beta q_T + \beta \cdot (1 + r_T) \cdot q_T \geq 0 \perp q_T \geq 0 \tag{4.6}$$

If r_T has the value -1, transits are modeled as competitive, whereas the value of 0 corresponds to a situation in which the transit country exerts market power (Cournot conjecture). If $q_T > 0$ is fulfilled, the equation (4.6) can be rewritten as:

$$P_E = \alpha - \beta q_1 - \beta q_T \cdot (2 + r_T) \tag{4.7}$$

With $q_T = q_2 + q_3$, this can be plugged into equation (4.4). With $r_2 = \frac{\partial q_3}{\partial q_2}$ and $r_3 = \frac{\partial q_2}{\partial q_3}$, this yields:

$$C_i - P_E + \beta \cdot (1 + r_i) \cdot (2 + r_T) \cdot q_i \geq 0 \perp q_i \geq 0 \text{ for } i = 2,3 \tag{4.8}$$

Equations (4.2) and (4.8) define the mixed complementarity problem for the stylized model. The important insight is that the inverse transit demand function can be included in the first-order conditions of producer 2 and producer 3. Turkey's inverse transit demand function is implemented in the global gas market model COLUMBUS accordingly as described in detail in appendix C.

4.4. Methodology: The Global Gas Market Model COLUMBUS

4.4.1. Model Description & Overview

In order to analyze the double marginalization induced by a multi-source transit country within a more complex market, the global natural gas market model COLUMBUS (cf. Hecking and Panke (2012), Growitsch et al. (2014), Hecking et al. (2016), Berk and Schulte (2017) as well as Berk et al. (2017)) is extended and applied. It is an intertemporal partial equilibrium model. Formulated as an MCP, it is able to account for strategic behavior of the upstream sector. Inputs are assumptions about production capacities, demand and gas infrastructure. COLUMBUS is a dynamic model which means that demand for investment into gas production and infrastructure are determined endogenously based on exogenously given economic factors such as investment costs and discount rates.

In its standard version, the COLUMBUS model is only able to consider strategic behavior of the vertical integrated suppliers defined "as a trading unit associated with one or more production regions" (Hecking and Panke, 2012). Transit countries, as in the focus of this chapter, are not associated with their own production region but can buy gas at their border from the neighboring countries. Therefore, the model is extended by introducing transit countries such as Turkey as profit-optimizing exporters. Technical details of the model extensions as well as a detailed technical description of the existing standard version of the COLUMBUS model can be found in appendix C.

The COLUMBUS model is calibrated with the data described in Section 4.4.2. Two calibrations with different conjectural variations are considered, one calibration to the year 2014 and one calibration to the year 2016. Both years are relevant because we aim on having calibrated configurations for an oligopolistic and a competitive upstream sector. As shown in Section 4.4.3, the European gas market of 2014 fits better to an oligopolistic setup, whereas the European gas market of 2016 fits better to the competitive assumption.

4.4.2. Input Data and Assumptions

Market Characteristics

In line with political and regulatory targets of the EU[5] (ACER, 2015b), further integration of the natural gas markets until 2030 is assumed. The EU market is aggregated into two clusters of countries: (1) a Northern & Western European (NWE) market and (2) a South Eastern European (SEE) market. The respective countries of each cluster are shown in Figure 4.2. The SEE market consists of the Balkan peninsula and Italy. Italy will be connected to the SGC by the TAP pipeline that is planned to become operational in 2018. The NWE market is composed of the remaining EU countries. The countries of each cluster are assumed to form an integrated market. Integration means that only one entry tariff (respectively exit tariff) has to be paid in order to ship gas into (respectively out of) the integrated market area.[6] A prerequisite for such a market design are investments in pipeline connections between the countries of the market area to reduce the risk of structural congestion.[7] An integrated market implies that there is only one gas price within each market area.

While the NWE market is already today characterized by a high degree of market integration in terms of sufficient infrastructure, competitive hub pricing and a high number of supply sources, the SEE market currently lacks connecting infrastructure and is dominated by Russian gas supply and oil-indexed long-term contracts (ACER, 2015a). However, there are various infrastructure projects (e.g. the CESEC initia-

[5]Within this chapter the EU includes the United Kingdom, Switzerland, Norway and all states of former Yugoslavia.

[6]Uniform entry/exit tariffs are assumed that are calculated as a capacity weighted average of historical tariffs from the ACER market monitoring reports (ACER (2014) and ACER (2016)). Basing the analysis on historical tariffs implies that the costs of further investments into the natural gas infrastructure would be regained at the exit points to the customers. For an interesting discussion of how to derive entry/exit fees in an integrated European market cf. Hecking (2015).

[7]Persistent congestion within a market area would lead to high redispatch costs that would have to be distributed to the gas customers within the market area.

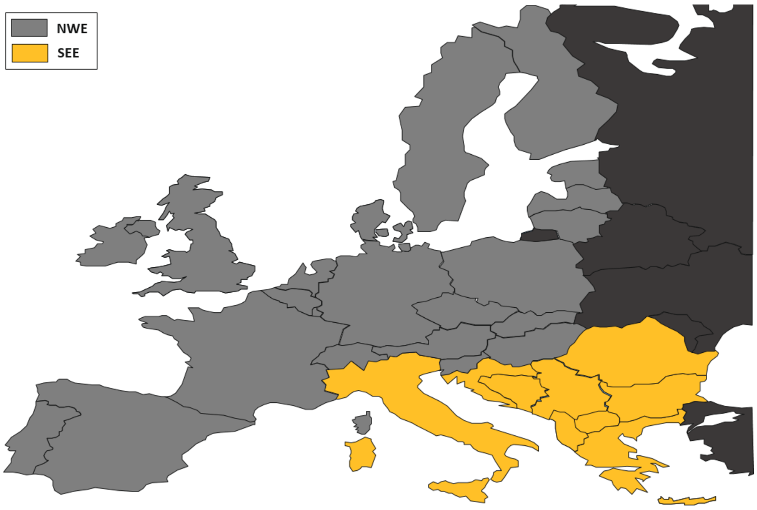

Figure 4.2.: Definition of the two clusters NWE & SEE

tive[8]) and regulatory incentives (e.g. agreements between the European Commission and Gazprom about destination clauses and pricing issues in LTCs[9] that aim on increasing the market integration within the SEE region. Hence, the assumption of an integrated market in SEE in 2030 is in line with the EU's long-term energy strategy. The modeling of two segments of the EU gas market allows a differentiation of effects of imports via the SGC on the NWE and SEE markets.

Demand

The model is based on linear demand functions as in Lise et al. (2008). Inputs for each demand region are a reference demand, reference price and point elasticity of demand.[10] The fundamental data source for the historical reference demand is the Natural Gas Information 2017 (IEA, 2017b). The future development of the reference demand is based on the projections of the Medium Term Gas Market Report 2015 (IEA, 2015a) and the New Policies Scenario of the World Energy Outlook 2015 (WEO) (IEA, 2015b). Hence, a nearly constant demand development in the EU is considered in this analysis. The point elasticities of demand are chosen in line with Growitsch et al. (2014) and Egging et al. (2010). Thus, for instance, for Europe a

[8] https://ec.europa.eu/energy/en/topics/infrastructure/central-and-south-eastern-europe-gas-connectivity
[9] http://europa.eu/rapid/press-release_IP-17-555_en.htm
[10] The general level of the demand is an input to the model as the reference demand. However, given the fact that the model is an equilibrium model, the equilibrium demand is an output of the model and can deviate marginally from the input demand path.

price elasticity of -0.25 is assumed. The European reference price is based on the Title Transfer Facility (TTF) price for the history, whereas the future development of reference prices is in line with (IEA, 2015b).

Production

The indigenous production of the EU is modeled exogenously, i.e. the respective EU reference demand is reduced by indigenous production. However, all external natural gas suppliers relevant for the EU such as Norway, Russia, suppliers from North Africa, but also potential suppliers from the SGC as Azerbaijan, Turkmenistan, Iran, Iraq and Israel as well as global players that are able to supply LNG to the EU, are modeled endogenously. The input data about production capacities, operational and capital costs is based on a comprehensive literature research of current and historic upstream projects. Data has been obtained from Seeliger (2006), Aguilera et al. (2009), Hecking et al. (2016), publications of the Oxford Institute for Energy Studies, current press notifications about new field discoveries / developments, and by exchange with industry experts.

Infrastructure

The COLUMBUS model encompasses the major elements of the global gas infrastructure including pipelines and LNG terminals. Some projects that have reached the financial investment decision (FID) status are exogenously given to the model (e.g. LNG terminals in the USA and Australia). The data for the existing pipeline infrastructure in Europe is based on the capacity map and the Ten Year Network Development Plan (TYNDP) of the European Network of Transmission System Operators for Gas (ENTSOG, 2015). In Turkey, the existing pipeline connections from Russia (Blue Stream), Georgia (Southern Gas Pipeline) and Iran (Tabriz-Ankara Pipeline) are modeled. In addition, the first stage of the Trans Anatolian Pipeline (TANAP) and the Trans Adriatic Pipeline (TAP) are considered in the model with commissioning in 2018 and 2020. Information regarding LNG liquefaction and regasification capacities has been gathered from publications of Gas Infrastructure Europe (GIE) (GIE, 2015) and from the LNG Industry Report 2015 which is published by the International Group of Liquefied Natural Gas Importers (GIIGNL, 2016). Facts about gas storage originate from reports of Gas Storage Europe (GIE, 2015) and the Natural Gas Information 2017 (IEA, 2017b).

Besides investment costs, short-run marginal transport costs are relevant for the market equilibrium. As already mentioned in Section 4.4.2, for the two considered European market areas, uniform capacity weighted entry/exit tariffs based on ACER (2014) for 2014 and on ACER (2016) for 2016 and 2030 are used.[11] The Ukrainian entry/exit tariffs are from Interfax (2015).[12] Transport costs for the SGC, for the South Caspian Pipeline (SCP), for the TANAP and for the TAP are based on a detailed analysis by Pirani (2016). A distance-based approach is applied to derive transport costs for other non-European world regions for which no detailed cost data is available.

The analysis is based on a pure economic rationale. This means that if not explicitly stated no political constraints are considered. Such constraints could be for example limited pipeline investment options between countries hostile to each other, or limited production capacities in countries that are politically unstable. While we know that political factors should be taken into account for a comprehensive analysis of Turkey's role in the SGC, we think that the economic perspective is helpful to understand drivers of all relevant stakeholders in gas markets including political actors.[13] Furthermore, the model does not consider discrete investment choices. Therefore, the simulation may also identify small capacity demands for investment into infrastructure that would not take place in reality.

4.4.3. Model Calibration

The calibration results are shown in Figure 4.3 and Figure 4.4. Figure 4.3 illustrates modeled and historical EU natural gas supply by source in 2014 and 2016. The respective bar in the middle depicts historical data from IEA (2017b). The left bar illustrates the COLUMBUS simulation results if the upstream sector behaves oligopolistically, and the right bar is the result for competitive behavior. For 2014, it becomes clear, that the oligopolistic case matches history better than the results with the competitive assumption. In the competitive case, about 5% more gas would have reached the EU gas markets compared to the historical imports. According to the model results, especially Russia withheld gas volumes in 2014. In 2016, there is

[11] Due to the fact that we consider only two market regions within Europe changes of Entry/Exit tariffs have a minor impact only.

[12] The assumed Ukrainian tariffs from 2015 imply that the Ukrainian route is the most expensive Russian export option to Europe. So despite not modeling the Ukrainian market power with respect to transit volumes endogenously, the Ukrainian market power is reflected in the exogenous tariff assumption.

[13] Additionally, there is literature that imposes similar restraints with respect to political factors, e.g. Berk and Schulte (2017).

an opposing picture. Figure 4.3 shows that the simulation of competitive behavior of the upstream producers matches reality better than oligopolistic behavior. In a market with oligopolisitc behavior, 6% less gas would have been consumed in 2016 compared to the actual consumption. However, when comparing both behaviors, it becomes clear that Russia was able to deter additional LNG imports by offering its gas at more competitive prices.

Furthermore, Figure 4.4 shows the historical average European import natural gas prices of 2014 and 2016.[14] It depicts also the price results of the COLUMBUS simulation, differentiated for the NWE and the SEE market as well as for an oligopolistic and a competitive upstream behavior for each respective year. Again, it can be seen that in 2014 the simulation of oligopolistic suppliers fits the reality best. For 2016, historic prices match better with a simulation of competitive suppliers.

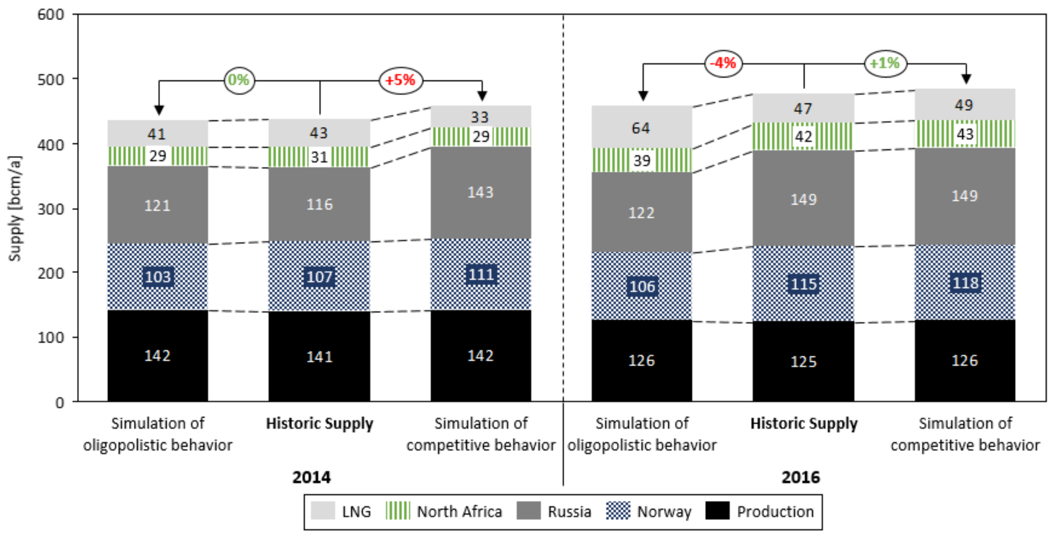

Figure 4.3.: Comparison of historical imports and model results in 2014 and 2016

However, it is hard to predict today if the upstream producers will behave oligopolistically or competitively in 2030. Therefore, both potential developments are considered in the following analysis.

[14]Average import border price as reported by the World Bank. Applied exchange rate: 1.32 EUR/USD (2014), 1.10 EUR/USD (2016)

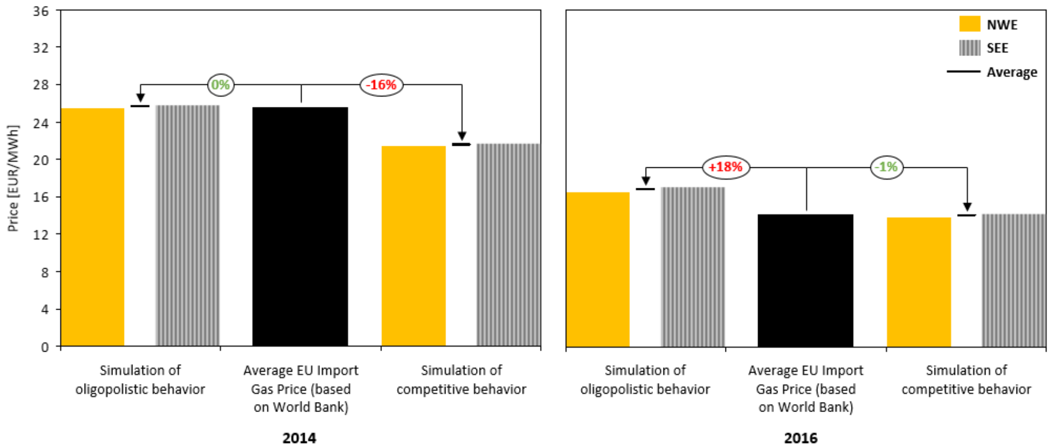

Figure 4.4.: Comparison of historical prices and model results in 2014 and 2016

4.5. Simulation Results

4.5.1. Turkish Transit Market Power in an oligopolistic European gas market

In order to analyze the effects of Turkish transit market power in an oligopolistic EU gas market (based on the conjectural variations for the model calibration to 2014), two different scenarios are investigated: (1) a scenario with competitive Turkish transits, i.e. the SGC upstream producers[15] can access the Turkish transmission system and have to pay only the transport costs, and (2) a scenario with Turkish transit market power, i.e. the SGC upstream producers have no own access to the Turkish transmission system and need to sell the volumes to an Turkish exporter (for an overview of all considered scenarios in this analysis cf. Table C.2 in Appendix C.3).[16]

Initially, a scenario with competitive Turkish transits is considered. The left bar of Figure 4.5 illustrates the simulated EU supply mix with competitive Turkish transits in 2030. Due to exhausting resources, the EU natural gas production declines from 125 bcm in 2016 to 98 bcm in 2030. For similar reasons, Norwegian imports are diminished from 115 bcm in 2016 to 65 bcm in 2030. In addition, Russian imports decrease from 149 bcm in 2016 to 112 bcm in 2030 in the oligopolistic scenario due

[15] SGC producers are potential suppliers from the Caspian region as Azerbaijan and Turkmenistan or from the Middle East as Iran, Iraq and Israel, that are also assumed to act strategically. Hence, they potentially withhold quantities to generate higher prices.

[16] In Appendix C.4.1, a sensitivity analysis on the conjectural variation of Turkey with values between -1 (competitive) and 0 (Cournot behavior) is considered.

to the withholding of quantities. The LNG market, which is assumed to be competitive, partly fills the resulting supply gap. Another part is filled by imports from the SGC via Turkey. On this route 45 bcm reach the EU market in 2030. Assuming that 10 bcm/a of SGC capacity is already financed in the TAP project and will be realized, this means that an additional pipeline capacity investment into the SGC of 35 bcm/a would be economically viable according to the model results. Obviously, Turkey and the SGC producers could benefit from an oligopolistic EU market situation with high prices in 2030. Hence, the share of EU's gas consumption that arrives via the SGC could be about 9%.

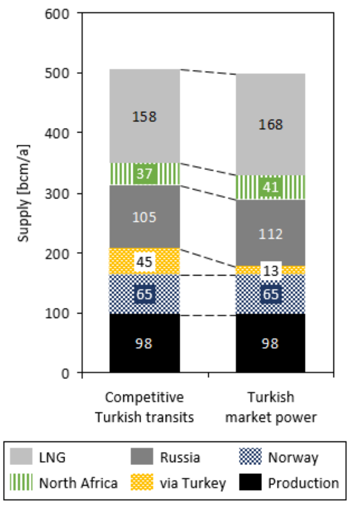

Figure 4.5.: EU supply mix per source in dependence on Turkish behavior in 2030

Besides the scenario with competitive transits, a scenario in which Turkey acts as a Cournot player, buying gas from the neighboring SGC producers and reselling it to the EU with a profit margin, is considered (a behavior called Turkish transit market power in the following).[17] The SGC producers are assumed to have pipeline access to the EU market via Turkey only. Because the SGC producers are modeled as Cournot players as well, this implies successive oligopolies with double marginalization as described in Section 4.3.[18] Pipeline investments on Russian territory by non-Russian

[17]In terms of the theoretical model described in Section 4.3 this means Turkey has a conjectural variation of 0.

[18]Russian transits through Turkey are still assumed to be competitive. Russian volumes are not bought by the Turkish Cournot player but can be sold to the European markets through Turkey directly by the Russian exporter that pays competitive transit fees. Turkey is not in the position to force Russia into a double marginalization structure as long as Russia has alternative channels to supply the European markets. Russia's direct investment options to Europe are not restricted and Russia rather prefers such direct routes to the EU as Nord Stream 2 due to lower costs compared to the Turkish transit option.

actors are thereby excluded. The assumption that SGC producers are not able to deliver gas via Russia to the EU is relaxed in Appendix C.4.2. The simulation results of the scenario when Turkey exerts market power are shown in the right bar of Figure 4.5. If Turkey exerts market power, Turkish re-exports would be much lower than in the competitive case at 13 bcm/a or additionally to the TAP capacity 3 bcm/a in 2030. For the EU this would mean higher gas prices and thus a slightly lower demand (-10 bcm/a). However, most of the gas that would originally be imported via Turkey could be replaced by higher LNG imports (+10 bcm/a) as well as higher direct imports from Russia (+7 bcm/a).

The effect of Turkish transit market power on the EU gas market prices in 2030 is shown in Figure 4.6.[19] The figure again compares a situation with (left bar) and without (right bar) the exertion of Turkish transit market power. Additionally, due to the differentiation of the EU markets into a NWE and a SEE market, regional prices in Europe can be analyzed. In the competitive scenario, prices are lower in SEE than in NWE in 2030. This is opposed to today's situation in which prices in South Eastern Europe are the highest on the continent. As already illustrated in Figure 4.4 in Section 4.4.3, the calibration results also show higher prices in SEE in 2014 and 2016 than in NWE. This can be explained with the fewer number of exporters that offer gas in the SEE market compared to NWE. If the SGC producers enter the market as new suppliers via Turkey, competition increases and leads to lower prices. However, if Turkey would exert market power, the positive effect of further market entries diminishes resulting again in higher prices in SEE. It can be observed that by the exertion of Turkish transit market power prices in NWE would be 4.3% higher, while prices in SEE would be 6.9% higher than in a situation with a competitively behaving Turkey. This points out that in an oligopolistic European gas market structure the strategic behavior of Turkey would have a significant economic impact, in particular on the SEE market.

Figure 4.7 shows the implication of Turkish transit market power on the profits of Turkey, Russia and the SGC producers. Additionally, the figure points out the impact on the EU consumer surplus. It shows the differences in profits and consumer surplus between a competitively acting Turkey and when Turkey exerts transit market power. In the competitive case, the Turkish profits are by definition 0. Thus, if Turkey exerts market power, it earns profits of 1.8 billion EUR in 2030. Due to less SGC gas within the EU gas markets, more Russian gas is exported to the EU in the transit market power case which leads to higher Russian profits of 2.5 billion EUR. However, profits

[19] Prices are in real terms based on EUR 2014.

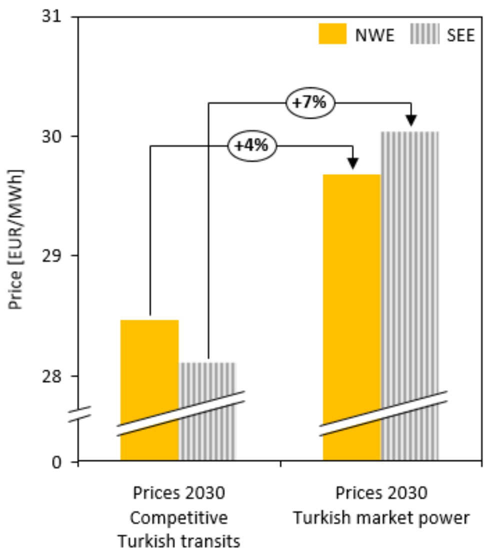

Figure 4.6.: Natural gas prices in dependence on Turkish behavior in 2030

of the SGC producers are 13.1 billion EUR lower in 2030. The EU suffers a loss of consumer surplus by 6.6 billion EUR.[20]

The results discussed so far have focused on transits of the SGC producers via Turkey to the EU. However, it is also important to look at the domestic Turkish gas market. Within this chapter it is assumed that Turkey would not exert market power in its domestic market. This is in line with a policy of the Turkish government to aim on low domestic gas prices that support economic growth. Thus, the domestic market can be directly supplied by all connected exporters. In the scenario with competitive Turkish transits, Turkey's modeled gas demand grows to 63 bcm in 2030 from 46 bcm in 2016. If Turkey exerts transit market power, its domestic demand is expected to amount to 65 bcm in 2030 according to the model results. In the market power case, the SGC producers have an incentive to ship gas to the Turkish domestic market instead of using the expensive transit option to the EU. Hence, the

[20] Summing up the differences of all rents shown in Figure 4.7, Turkish market power leads to a net welfare loss of 15.4 billion EUR compared to a scenario with competitive Turkish transits given an oligopolistic upstream market. This welfare loss could be avoided by contractual relations. In a setup with market power by Turkey, especially long term contracts with minimum take-or-pay obligations between European importers and the SGC producers could lead to fixed volumes flowing through the SGC. Additionally, a transit contract with Turkey could be signed. Another possible contractual relation would be a joint-venture of the SGC producers, Turkish transmission operators and European importers. Besides neoclassical approaches, future research could consider transaction cost based theories for a comprehensive analysis of the most suitable contractual relations in the SGC.

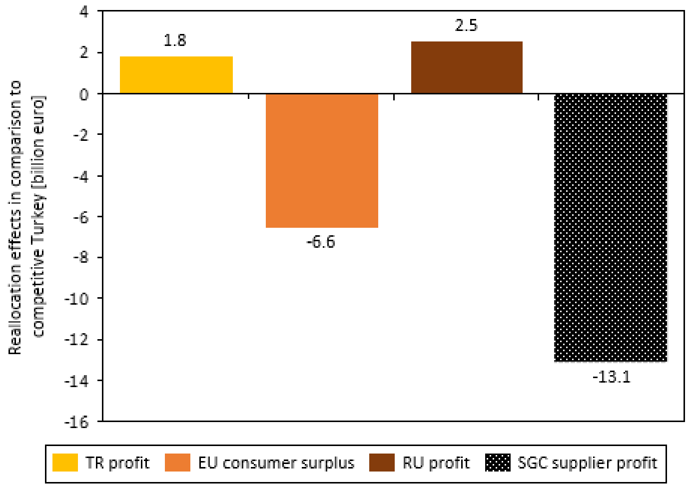

Figure 4.7.: Development of profits and consumer surplus if Turkey exerts market power in 2030

competition in the Turkish domestic market increases leading to 5% lower gas prices and hence to 1.1 billion EUR additional Turkish consumer surplus compared to the case with competitive Turkish transits. Thus, Turkey benefits twice by exertion of transit market power: (1) by profits from transits and (2) by a higher consumer surplus in its domestic market.

Figure 4.8 shows the origin of the gas exports of Turkey to the EU in 2030. It compares the transits for both considered scenarios (with and without the exertion of Turkish transit market power). If Turkey behaves competitively, about two thirds or 30 bcm of Turkish transits to the EU is Azerbaijani gas from the Shah Deniz field in the Caspian Sea. Since no Iranian sanctions are considered (pure economic rationale), an additional 11 bcm of Iranian gas would reach the EU market via Turkey in 2030. This figure seems to be quite small compared to the fact that Iran has the world's largest natural gas reserves (BP, 2016). Nevertheless, according to the model results, Iran supplies other markets than the EU such as Pakistan, India or the global LNG market.[21] Furthermore, about 4 bcm of expensive Israeli off-shore gas from the Mediterranean Sea would reach the EU. Turkmenistan and Iraq would not transit gas via Turkey to the EU due to comparably low price signals and the far distance. They would only supply the Turkish domestic market (both would deliver about 7 bcm). Whereas Turkmenistan would supply gas to Asian customers, the exports from

[21] For a more detailed discussion about Iranian exports see Berk and Schulte (2017).

Iraq are limited due to the increasing indigenous demand (mainly gas demand from the crude oil production).

On the contrary, if Turkey exerts market power, nearly all of the 13 bcm gas transits that would reach the EU would be from Azerbaijan. The reason lies in the country's missing alternative demand sinks and thus the strong Azerbaijani dependence on Turkey compared to Iran that can ship gas to the above mentioned alternative markets. Gas from Israel, however, would be too expensive and not exploited. Again, Turkmenistan and Iraq would deliver the Turkish domestic market only (Turkmenistan: 12 bcm, Iraq: 10 bcm). Besides that, Turkmenistan would focus on non-European markets. Against this background, Appendix C.4.2 considers a sensitivity analysis in which Azerbaijan can ship gas through Russian territory to the EU. In such a setup, market power would earn Turkey profits in the range of of 0.4-0.5 billion EUR instead of 1.8 billion EUR in the case without Russian transits.

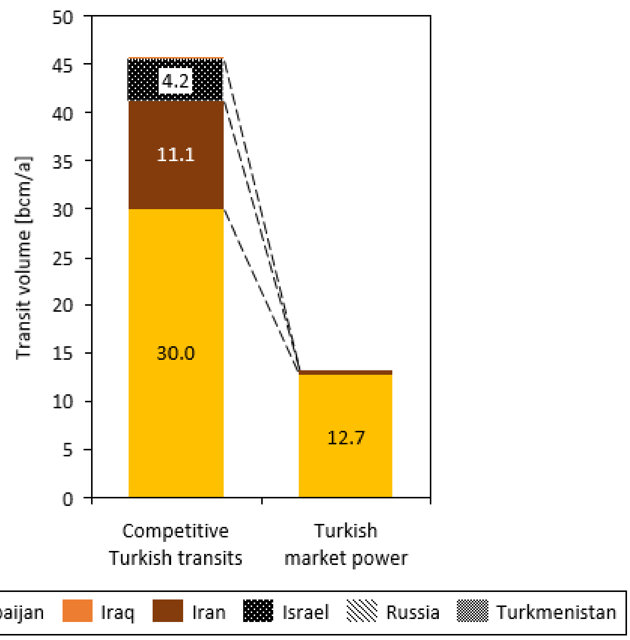

Figure 4.8.: Turkish gas transits into the EU per source in dependence on Turkish behavior in 2030

4.5.2. Impact of Turkish Transit Market Power in a competitive European gas market

In the next step, the effects of Turkish transit market power in a competitive EU market is investigated. Hereto, we use the same conjectural variations as for the model calibration for 2016 (cf. Section 4.4.3). However, as already shown by Berk and Schulte (2017)[22], the chance of Turkey to become an important transit country for the EU is quite limited under competitive market conditions. There is only a minor demand for expensive gas from the SGC in a competitive EU gas market setting with a nearly constant future gas demand development. Similar results are found in this chapter.

If Turkey behaves competitively and SGC producers have to pay only the current TANAP transit fees, 23 bcm of gas would pass through Turkey to the EU in 2030. Nearly 18 bcm would come from Azerbaijan and approximately 5 bcm form Iran. Gas from Israel would be too expensive to reach the EU markets. However, even in this situation Turkey would be able to exert transit market power. Hereby it would earn profits of 0.5 billion EUR. Nonetheless, if Turkey would exert market power in such a competitive environment, the potential of the SGC project to diversify the EU gas markets is negligibly small. Approximately 5 bcm from Azerbaijan would reach the EU gas markets. That means that even the capacity of the already financed first stage of the SGC would be oversized. That underlines the minor importance of the SGC under competitive market conditions.

4.6. Conclusion

The results of the chapter illustrate that Turkey has the potential to exert market power in the EU natural gas markets if an oligopolistic market structure (similar to the historical gas market in 2014) is assumed. If Turkey behaves competitively in this market environment, 45 bcm of Turkish transit volumes would arrive in Europe in 2030 according to the model outcome. In such a situation, gas prices in the SEE region could be lower than in the NWE region because the SGC producers would increase the competition, in particular in the SEE region. In the case of Turkish transit market power, however, the transits through Turkey would be reduced to 13 bcm in 2030, illustrating a big potential to withhold quantities from the markets.

[22] A further study that investigates the role of the SGC under competitive market conditions is Hecking et al. (2016).

According to the model outcome, gas prices in the NWE region would be 4.3% higher in this setting in 2030 compared to a situation with competitive Turkish transits. However, SEE would be most significantly affected by 5.9% higher prices if Turkey exercises market power. The consumer surplus of the EU would be 6.6 billion EUR lower compared to the case in which Turkey behaves competitively. If Turkey would only withhold quantities to the European markets and not to its domestic market, lower gas prices in Turkey would be the consequence. Hence, Turkey could increase its consumer surplus (by 1.1 billion EUR) besides earning profits from transits (1.8 billion EUR) making it attractive for Turkey to use the market power option.

However, in a competitive future gas market setting (similar to the historical gas market in 2016), gas imports via Turkey and the SGC would be only of minor importance, even if Turkey behaves competitively. Hence, also the Turkish potential of pursuing transit market power is limited.

Our analysis illustrates that the economic raison d'être for the SGC is only given for an EU gas market that is characterized by oligopolistic natural gas suppliers. However, in this oligopolistic environment, Turkey could benefit from exerting market power and hereby eliminate the potential benefits of the SGC for the EU. As a policy implication, the EU could prefer direct connections between supply and demand avoiding new dependencies on transit countries. Other potential policy measures would be the harmonization of Turkey's energy laws with EU directives that guarantee a non-discriminative access to transmission grids, and policies incentivizing contractual relations between the SGC producers, Turkey and European importers. Additionally, the EU as well as the SGC countries could make concessions in other sectors of the economy if Turkey allows competitive transits given that low or no tariffs to access foreign markets can be negotiated with exchange deals in the same or other sectors of the economy.

5. Diversification at any price? – The European Union's diversification ambitions for natural gas

The launch of the European Commissions Third Energy Package in 2009 was the founding of the Agency for Cooperation of Energy Regulators - ACER. The Agency's overall mission is to complement and coordinate the work of the national energy regulators and the completion of a single EU energy market. In doing so, the Agency evaluates the level of diversification for natural gas of each EU member state. To this end, ACER applies several metrics that require a predefined score, e.g., a Herfindahl-Hirschman-Index (HHI) of at most 2000.

Within this work, the effects of compliance of ACER's diversification scores is analyzed, in particular for the HHI. In a first step the relevant market defined by ACER to calculate the HHI is questioned. Secondly, a realization of ACER's predefined score for the HHI is simulated for the year 2025. In order to do so, the natural gas market model COLUMBUS is extended and applied. The simulation results show that a realization of the metric scores is possible. However, the fulfillment would largely impact gas flows as well as have strong economic implications. On the one hand, it would replace natural gas flows from eastern Europe (e.g. the Russian Federation) to western Europe (e.g. LNG imports). Hence, Russia would have to reduce its gas supply by around one third in 2025. On the other hand, due to the ban on low-cost Russian gas, the diversification would result in higher European natural gas prices and hence a loss in consumer surplus of 13 billion Euro.

5.1. Introduction

In 1998, the European Commission published its First Gas Directive (98/30/EC), which focused on the liberalization of the EU natural gas markets and the development of one internal EU market. Five years later in 2003, the Second Gas Directive (2003/55/EC) was published. It included for the first time an article on "Monitoring of Security of Supply" (Article 5), which assigned the national regulation authorities (NRA) responsibility. In 2009, as part of the Third Energy Package, the Commission launched the Third Gas Directive (2009/73/EC) focusing on a further enhancement of the internal market. With regard to natural gas, the package included two new regulations: one on the conditions for the access to natural gas transmission networks (EC No 715/2009) and one on the establishment of the Agency for Cooperation of Energy Regulators (ACER) (EC No 713/2009). The European agency established by the latter regulation was meant to encourage better cooperation of the NRAs as well as facilitate the implementation of the single EU energy market.

Two years later in 2011, ACER published the Gas Target Model (GTM), a structural framework with the vision of "a competitive, secure European gas market that benefits all consumers" (ACER, 2015b)[1]. To reach this vision, ACER focuses on the development of a 'well-functioning'[2] internal wholesale market for natural gas and defined several criteria with a certain score that should be fulfilled, e.g., to measure the level of diversification[3]. Furthermore, ACER was to monitor the functioning of gas markets and report to the European Parliament and the Commission (Article 11). By publishing an annual monitoring report, the agency should identify competition barriers of the internal market for natural gas and suggest possible solutions. In its recent monitoring reports, ACER criticizes the low diversification and hence the vulnerability of the European gas markets against the exertion of market power (ACER, 2017a).

The overall objective of this paper is to investigate ACER's diversification metric – the HHI – and analyze what a realization of the defined score would imply for the EU gas market in terms of its natural gas supply mix as well as the economic conditions.

Beside the literature on EU regulations, the research is related to two further streams of literature that address the mentioned research questions: (1) literature that focuses on diversification and (2) literature on numerical natural gas market models that can be used to simulate the degree of diversification of a future EU gas market. With respect to the first stream of literature, Stirling (1998) provides a comprehensive overview on different approaches to evaluate diversity in economics in general. With a view on natural gas markets, diversity or the diversification of supply sources often go hand in hand with the discussion on either security of supply or

[1] The GTM was reviewed and updated in 2015 (ACER, 2015b).

[2] Joskow (2006) defines a 'well-functioning' wholesale market as a market in which either suppliers offer their product at marginal (opportunity) costs such that the last increment of supply is setting the price or prices exceed marginal costs at limited number of times in which supply capacity is constrained.

[3] The GTM is discussed in more detail in the next section.

market concentration as an indication for market power. The literature that focuses on diversification to address security of natural gas supply issues had its heyday particularly in the course of the two Russia-Ukrainian gas conflicts in 2006 and 2009[4]. However, since then, the EU addressed several measures to avoid security issues such as the launch of regulations[5] and the financing of PCI[6] infrastructure projects. In addition, the Nord Stream pipeline was commissioned in 2012, which made Russia but also the EU more independent from gas transits via Ukraine. As a positive result, today's gas markets are less vulnerable against potential supply disruptions, as shown by several studies (Hecking, 2015, Hecking et al., 2016, Martinez et al., 2015).[7]

However, in the last few years, diversification has been used more in the context of ensuring a well-functioning market or well-diversified supply, which will result in a more competitive EU price formation (ACER, 2017a). Hence, the focus lies more on the competitiveness of gas markets and market concentration in general, instead of supply security. As mentioned before, this also holds true for ACER, which applies, e.g., the HHI on historical data to evaluate if a market is well-functioning. The application of diversity indices is well-established in economics. Hence, indices like the HHI are often applied as (inverse) indicators for competition intensity and market efficiency (Bester, 2012). For example, based on Cowling and Waterson (1976), Bester (2012) shows for companies within one industry that the competition intensity of a Cournot market is inversely proportional to market concentration or the ratio of the HHI and demand elasticity. The Federal Trade Commission of the U.S. Department of Justice or by the European Commission also apply an HHI to evaluate antitrust concerns of horizontal mergers (European Commission, 2004, Federal Trade Commission, 2010). However, there is no causal relationship between market concentration and the market efficiency, and Cowling and Waterson (1976) show the relationship only for the case when all companies considered have the same marginal costs. Market shares depend on factors such as a company's cost structure and the type of competition. Hence, a reduction in production costs that may increase a company's market share and therefore the market concentration may have indeed a positive effect on welfare (Bester, 2012). Also Demsetz (1973) and Peltz-

[4]See, for instance, Bettzüge and Lochner (2009), Cohen et al. (2011), Le Coq and Paltseva (2009, 2012), Månsson et al. (2014).

[5]Regulation (EC) No. 2017/1938(European Commission, 2017) or Regulation (EC) No. 994/2010 (European Commission, 2010).

[6]EU Projects of Common Interest.

[7]For a more comprehensive overview of security of supply indices found in the literature, see also Schulte (2014), Sovacool (2012), Sovacool and Mukherjee (2011).

man (1977) argue that a high market concentration may indeed be a signal of a high market efficiency.

The modeling of natural gas markets allows the scenario simulation and analysis of possible future developments, e.g., a fulfillment of ACER's diversification scores. Therefore, the second stream of literature that is of interest for this work is literature on natural gas market models[8]. A first important model in this context is the GASTALE model, developed by the Energy Research Center in the Netherlands (ECN) (Boots et al., 2003). It is a partial equilibrium model formulated as a mixed complementarity problem (MCP) and is able to simulate market behavior of different agents. In addition, a later version of the model is able to endogenously identify demand for investment (Lise et al., 2008, van Oostvoorn and Lise, 2007). However, GASTALE is limited in its spatial resolution: It models the European market with only two demand and five supply regions, which would make an analysis on a EU member state level impossible. In comparison, the TIGER model has a much higher granularity. The TIGER model of the Institute of Energy Economics (EWI) at the University of Cologne was developed by Lochner (2011c) and applied in several studies[9]. TIGER is a linear optimization model which stands out with its high spatial resolution. Among others, it involves all European underground gas storages and LNG import terminals and has at least one demand region per country. However, in its standard version, TIGER does not model investment endogenously, which is important for an efficient analysis of supply diversification. Beside the aforementioned limitations for the analysis at hand, both of the models described focus on the European gas market only. Global interdependence, e.g., the LNG market, is only considered in a simplified way as an exogenous parameter[10]. The COLUMBUS model described, extended and applied in Section 5.3 addresses the shortcomings of the mentioned models.

The remainder of this chapter is structured as follows: Section 5.2 provides an overview of ACER's Gas Target Model and challenges its diversification metric, the HHI. Subsequently in Section 5.3, the COLUMBUS model is extended and applied to simulate the gas market situation in 2025 with and without an achievement of ACER's predefined score for the HHI. Hereby, it is possible to analyze the implica-

[8]The gas market models mentioned are only a selection of the variety of models that are available in the literature. For a more comprehensive overview, please see Schulte (2014) and Schulte and Weiser (2019a).

[9]See, e.g., Dieckhöner (2012), Dieckhöner et al. (2013), Lochner (2011a,b), Lochner and Bothe (2007), Lochner and Dieckhöner (2011, 2012), Lochner and Richter (2010).

[10]In a new version of the TIGER model, it is possible to include LNG supply functions derived by the COLUMBUS model, see Hecking and Weiser (2017).

tions of ACER's diversification targets on the EU gas markets. Finally, Section 5.4 concludes.

5.2. ACER's Gas Target Model

5.2.1. ACER's diversification metric

In its GTM, ACER defines how a 'well-functioning' gas market can be realized. One main pillar of the model comprises entry-exit zones with virtual trading points and market integration, which should be served by an appropriate level of infrastructure that enables the gas to move freely between market areas. In this context, the interconnections and the implementation of the Network Codes, as described in Regulation No 715/2009 (European Commission, 2009b), also play a key role. In order to assess whether or not the wholesale market is well-functioning, ACER's GTM provides a series of criteria or metrics that are applied on a member-state level in a yearly monitoring report. The metrics are evaluated according to an optimal score that should be achieved and can be pooled into two categories, according to their market characteristics: (1) market participants' needs metrics and (2) market health metrics. While the former should indicate how liquid a market is, the latter should indicate if the markets are structurally competitive, resilient and have a sufficient degree of diversity of supply.

For the analysis at hand, the focus lies on the aspects of upstream competition and diversity of supply. Hence, particularly the Herfindahl Hirschmann Index (HHI), one of the health metrics, is in the center of the discussion. The HHI measures supply side market concentration and is defined as follows:

$$HHI = \sum_{i=1}^{n} (a_i \cdot 100)^2 \tag{5.1}$$

While i is the individual supplier, n is the number of suppliers and a_i the individual suppliers market share. According to ACER, the HHI of a considered market should be lower or equal to 2,000. Note that requiring HHI to be lower or equal than 2,000 implies that there need to be at least five suppliers in a market.[11]

[11] Note that a further health metric requirement of ACER is that the number of supply sources is at least 3. Hence, if ACER's requrement for the HHI is reached, the requirement for the number of supply sources is reached, too.

5.2.2. The definition of the relevant market

In its annual monitoring report, ACER evaluates the health metrics and hence the HHI on a member state level. Hence ACER implicitly defines the member state as the relevant market. By doing so, ACER neglects the EU internal gas market whose intention are free gas flows between the member states realtive to price signals. In particular, in western Europe, gas markets have been physically well interconnected for a long time. Hence, gas flows between the nations are easily possible, if necessary. But also most of the eastern gas markets have developed very well in terms of market integration in recent years, with new pipelines and compressor stations became operational. The new infrastructure allows reverse gas flows from the liquid western European gas hubs to the eastern markets. Hence, by applying the HHI on historic supply shares, ACER undermines the existing supply capacity of the countries, which may allow imports from alternative supply sources.

Also Peters (2018) argues that the application of the HHI on a national level is in general questionable. Due to well working natural gas hubs, particularly in the Northwest-European traded markets, it becomes hard to track the origin of gas supply after it has entered the market. In ,e.g., the Dutch hub Title Transfer Facility (TTF) gas has several options to enter the market: via the Dutch LNG terminal Gate, via pipeline from Norway, the United Kingdom (UK), Germany or from domestic production. However, since the gas has already entered the market, molecules become anonymous and a tracking of volumes is hardly possible.

Hence, the discussion about the relevant market and its integration is closely related to the discussion of the presence of outside options. If markets are well interconnected and have an access to alternative supply sources, the high market concentration induced by a single supplier is only of minor importance. Lithuania, e.g., was, until 2014, an isolated market that was fully dependent on Russian gas supplies. This allowed Russia to enforce higher prices compared to other countries. However, after building an LNG terminal in 2014, Lithuania's bargaining power against Russia changed, resulting in lower gas prices (Schulte and Weiser, 2019a). Today the Russian market share in Lithuania is more than 80%, such that a HHI would be at least 6400 (IEA, 2018a). However, due to the presence of additional capacity in the form of a LNG terminal, Russia is not able to enforce higher prices. The same can be observed on a EU level. As already shown by Hecking et al. (2016), the European gas market has several options to diversify its natural gas supply. However, LNG imports in particular could be increased if suppliers with high market shares try to exert market power. Hence, the globally-determined LNG price would set a maximum price ceiling to the European market that would come into force if prices reach the level of the LNG price.

In the future, it is likely that the internal EU gas market will further progress and become even more integrated, as addressed by the EU Directive 2009/73/EC (European Commission, 2009a). The internal market will continue to promote free gas flows between all EU member states such that gas will only follow price signals. To enable this development, further financial support for physical connections between the member states, e.g., a stronger support for the EU projects of common interest (PCI) is important and should be provided by the EU. In addition, ACER's gas market integration and connection tools (e.g., market merger), as suggested in the GTM (ACER, 2015b), may promote further integration. However, an implementation of these integration tools does not mean that ACER will fulfill its self-defined HHI thresholds, which are calculated on a member state level. A better connection of the markets and further physical infrastructure between the member states should be interpreted as an insurance, allowing for alternative gas imports if a market is not functioning well due to supply disruptions or the exertion of market power.

5.3. Market Concentration in the Future EU Gas Market - A Model-Based Analysis

5.3.1. Methodology - The COLUMBUS Model

Model description and extensions

To analyze the economic effect of an achievement of ACER's predifined score for the HHI, the global gas market model COLUMBUS was extended and applied. The model was initially developed by Hecking and Panke (2012) and used to address several gas market-related research questions[12]. COLUMBUS is a spatial and intertemporal equilibrium model. Formulated as a MCP, the model allows the simulation of the market behavior of different actors. The model has a high spatial resolution (e.g., 21 modeled regions for the EU[13]). This allows diversification to be analyzed for most of the member states. Assumptions on gas infrastructure, production ca-

[12]See, for instance, Growitsch et al. (2014), Hecking et al. (2016), Berk and Schulte (2017), Berk et al. (2017) or Schulte and Weiser (2019b).

[13]All large gas-dependent member states are included. The Baltic States are modeled as one region as well as the nations of the former Socialist Federal Republic of Yugoslavia. Malta and Cyprus are not considered; Luxembourg is aggregated with Belgium.

pacities and demand are based on public data and are inputs in the model. Based on economic factors such as investment and production costs or discount rates, the model identifies demand for investment endogenously. This model characteristic is crucial for the analysis at hand because, in some countries, investment will be necessary to diversify supply. Furthermore, COLUMBUS also considers the global interdependence of the LNG market and its impact on Europe. Because LNG plays a crucial role for the diversification of the European gas markets, this is a further advantage to help answer the research questions. A detailed technical description of the COLUMBUS model is provided in Appendix D.

ACER's HHI benchmark was implemented in the COLUMBUS model as a maximum import constraint[14]. This results in a limitation of the market share for large natural gas suppliers in general and especially for the Russian Federation. A detailed technical description of the model extension is provided in appendix D.2. The HHI is calculated ex post, based on the simulated gas flows and the respective company shares of a country[15]. However, due to the fact that for the main supply countries such as the Russian Federation the major national gas companies have a monopoly on (pipeline) exports, an ex-post calculation leads to the same results. Subsequently to the ex-post calculation of the HHI, the import constraints of each country and supplier are adjusted and the model is re-simulated in an iterative process until a HHI of at most 2000 is reached. The company shares of the modeled supply countries are assumed to be constant over the horizon simulated.

Data Input

Spatial equilibrium models like COLUMBUS are based on a large number of fundamental data such as demand, supply and infrastructure that are fed into the model. Based on the approach of Lise et al. (2008), the COLUMBUS model relies on linear demand functions. The reference natural gas demand is an exogenous input to the model but, due to price elastic functions, the resulting demand is sensitive to the price. Demand is derived on a country level for the sectors household, industry and power. Point elasticities of sector and country-specific demand are in line with Growitsch et al. (2014) and Egging et al. (2010). The reference demand data is based on Natural Gas Information (NGI) 2017 (IEA, 2017b) for historical values as

[14]A direct implementation of the HHI constraint would be the first-best option. However, due to the quadratic character of the HHI, the implementation in numerical simulation problems is limited.

[15]In COLUMBUS countries are modeled, not companies. The company shares are based on desk research and are shown in Table D.1 in Appendix D.3.

well as on the Market Report Series Gas (GAS) 2017 (IEA, 2017a) and the New Policies Scenario of the World Energy Outlook (WEO) 2017 (IEA, 2017c) for the future projections. As a consequence, a nearly stable demand development is assumed for Europe.

While production of net importers is modeled exogenously, production of net exporters is modeled endogenously. The underlying data is based on a comprehensive literature analysis of historical and current upstream project developments. Among others, data was sourced by Hecking et al. (2016), Aguilera et al. (2009) and Seeliger (2006) as well as publications by the Oxford Institute for Energy Studies. Furthermore, long-term contracts (LTC) between different countries are an important characteristic of the supply side and also considered in COLUMBUS. LTC data is based, among others, on Neumann et al. (2015).

Given its importance for the natural gas market, COLUMBUS includes a large data set for infrastructure including pipelines, LNG liquefaction and regasification terminals as well as storage facilities. The data on existing and planned infrastructure capacities[16] is an input to the model and is based on different sources such as the map's of European Network of Transmission System Operators for Gas (ENTSOG) and Gas Infrastructure Europe (GIE) (ENTSOG, 2017, Gas Infrastructure Europe, 2017, GIE, 2018), the LNG Industry Report 2017 (GIIGNL, 2017), different IEA publications (IEA, 2017a,b,c) and the Ten Year Network Development Plan 2018 (ENTSOG, 2017). Future demand for infrastructure without financial investment decision (FID), however, is identified endogenously based on different parameters such as, e.g., investment costs or future price developments.

Calibration

The model is calibrated and back-tested for the year 2016. In line with Schulte and Weiser (2019b), a competitive market environment is assumed. Figure 5.1 shows the calibration results regarding the HHI for 2016. The HHI reported by ACER (ACER, 2017a) is plotted on the horizontal axis. The EU member states[17] are represented by

[16]Only projects with the status financial investment decision are given exogenously to the model (e.g., LNG projects in the USA or Australia).

[17]The islands Malta and Cyprus are not modeled in COLUMBUS due to their missing connection to the European gas network system. The Baltic States are modeled as one node, hence it is not possible to calculate an individual HHI for each country. The same applies for Croatia and Slovenia, which are modeled within a region that represents all countries of the former Socialist Federal Republic of Yugoslavia. Luxembourg is modeled together with Belgium; however, due to the small size of their markets, the impact on the total European costs is comparably low.

the bubbles. The size of the bubble indicates the market size, i.e., the member states' annual gas consumption. In 2016, only four member states (namely the United Kingdom, Sweden, Belgium and France) reached ACER's requirement and had a HHI below 2000. However, most of the EU members have not achieved the requirement.

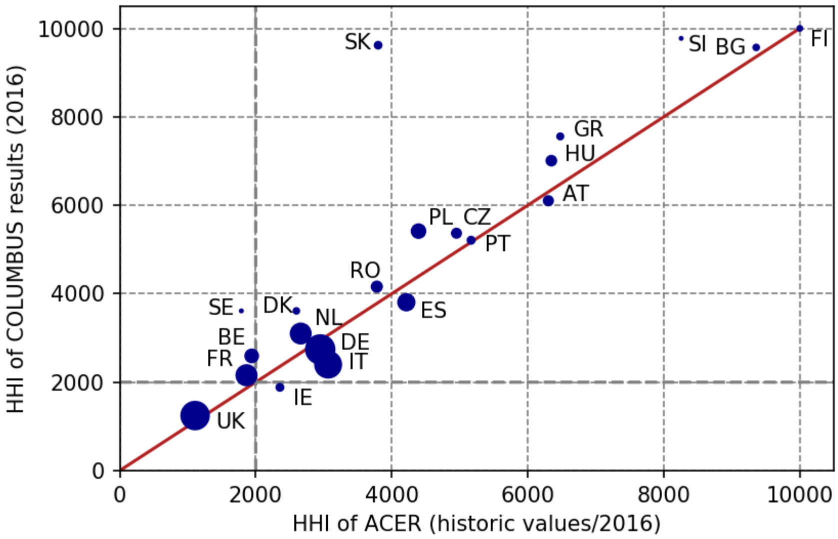

Figure 5.1.: HHI comparison: ACER vs. COLUMBUS simulation results

The vertical axis of Figure 5.1 shows the calibration results of the COLUMBUS model for 2016. The closer the member states' HHI is to the red bisectrix, the better the COLUMBUS results reflect ACER's calculations. It is obvious that, in general, the COLUMBUS results fit ACER's historical values quite well. However, not all historical values are met. In particular, this results from the lack of data that ACER provides for the calculation of its HHI[18]. The values for the HHI calculation for the study at hand are based on the gas imports simulated with the COLUMBUS model and the respective company market shares that were derived by an own data research. The largest deviation is shown for Slovakia, which imported in reality natural gas from the German spot market despite the fact that its LTC with Russia is higher than its demand[19].

[18]According to ACER (2017b), the market shares of the upstream companies to the supply sources were assigned based on desktop research, which is not published by ACER.
[19]This specific situation is not covered by the COLUMBUS model.

5.3.2. Scenarios & Results

Scenario definition

In order to analyze the economic impact of the implementation of ACER's diversification ambitions – the achievement of the predefined HHI score – two different scenarios are analyzed: (1) a Reference Scenario and (2) an ACER Target Scenario. The Reference Scenario assumes 'business-as-usual' conditions and forecasts the development of the future natural gas market under the assumption of current market policies and economics. In the ACER Target Scenario, however, the score for the HHI intended by ACER need to be achieved in the future. More specifically, this means that each EU member state should have a HHI of at most 2000. Thereby, the focus year for the model simulation is 2025, which is the year ACER addresses in its "A Bridge to 2025" conclusion paper (ACER, 2014). A comparison of both scenarios draws conclusions about the general impacts and the economic effects of an achievement of ACER's diversification ambitions.

The Reference Scenario

The Reference Scenario simulates the European natural gas market under business-as-usual conditions up to the year 2025. Hence, there is no requirement regarding diversification, and only economics decide where the member states receive their gas imports from. The resulting HHI for the member states considered is shown in Figure 5.2. While the horizontal axis shows the COLUMBUS simulation results for 2025, the vertical axis depicts the results for 2016. For 2025, it is obvious that only a few EU member states would fulfill ACER's HHI requirement of lower than 2000, namely the United Kingdom, France, Italy and Greece. While the former two countries already achieve ACER's HHI requirement today due to their distance to the Russian Federation and a well-fitted LNG import infrastructure, the latter two countries would achieve the HHI requirement and hence a reduction of market concentration, in particular, by the import of contracted gas volumes from Azerbaijan[20].

The EU member states can be separated into two clusters: western states (blue), which are generally better diversified, and eastern states (orange), which show a higher market concentration due to a higher share of Russian gas. Only two of the

[20] Italy has a LTC with Azerbaijan of 8 bcm annual contracted quantity (ACQ) and Greece of 1 bcm. The take or pay (TOP) amount of both LTCs is assumed to be 70%. This 70% would enter the market despite the comparably high costs of gas that is imported via the Southern Gas Corridor (see also Berk and Schulte (2017), Schulte and Weiser (2019b)).

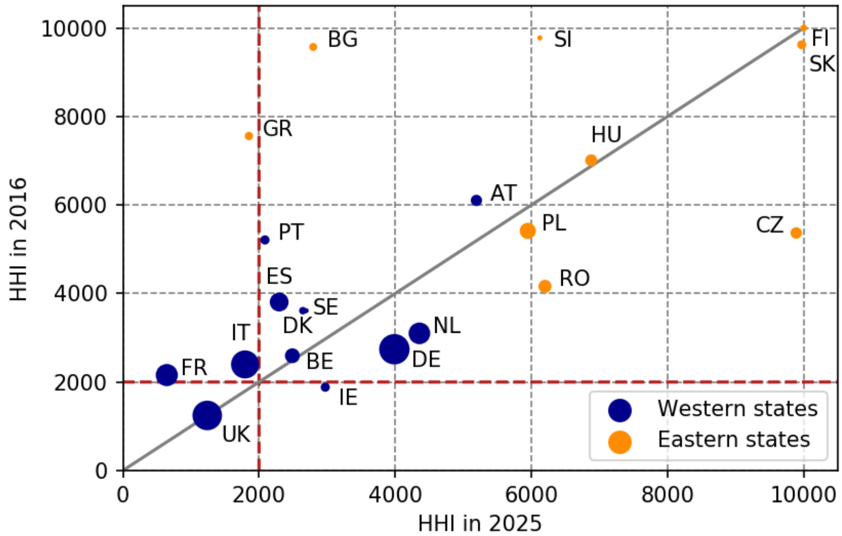

Figure 5.2.: Scenario 1: COLUMBUS simulation results for HHI

eastern European member states reach a HHI that is lower than 3000: Greece, as already mentioned, and Bulgaria. Bulgaria would benefit from its new interconnection to Greece via the so-called 'Gas Interconnectror Greece Bulgaria' (IGB) but also from imports via the Southern Gas Corridor[21] (SGC). The remaining eastern states perform much worse in terms of the HHI. Due to its geographical distance, the Russian Federation would have a large share of the eastern countries' natural gas supply. Finland would be fully supplied with Russian gas. Russian gas would be also dominant in Slovakia and the Czech Republic, which show a HHI of more than 9000. Furthermore, Poland, Hungary and Romania would record a HHI of more than 5000. While in Poland and Hungary Russian gas would play a major role, Romania would be mainly supplied by companies that exploit domestic resources.

Among the western states, there are big markets such as Italy, France and Spain, that improve their market concentration in 2025 compared to today. In particular, these are countries with access to the global LNG market. However, other large markets such as Germany and the Netherlands would perform worse in terms of their HHI. While the domestic Dutch production further declines, there is more space for Russian gas imports. Nord Stream 2, an expansion of the current direct pipeline connection between the Russian Federation and Germany, supports the supply of

[21]Bulgaria has a LTC with Azerbaijan with an ACQ of 1 bcm/a.

Russian natural gas to both markets[22]. The model identifies the investment into the pipeline based on economic fundamentals[23]. Due to the sufficient physical connection of the German and the Dutch market, low-cost Russian re-exports via Germany are the preferred Dutch option. Hence, LNG plays only a minor role in that market.

A look at the EU level shows a different picture regarding market concentration. When considering the EU as one integrated market and aggregating the member states' supply mix, a HHI of 1640 would be reached for 2016. Hence, considering the EU gas supply as shown in Figure 5.3, ACER's requirements would already be achieved today, compared to a calculation on a national level as shown in Figure 5.1, despite the fact that the Russian Federation or Gazprom has a market share of 31%. The reason for the comparable low HHI on an aggregated European level is twofold: First, the indigenous EU production in particular has a much more diversified company structure. Second, the aggregated LNG supply, with its different origins and companies involved, is heterogeneous. When looking at 2025, the EU supply mix changes dramatically. However, the overall heterogeneity remain on a constant level. Due to exhausted resources, the EU indigenous gas production declines. The same applies for Norway and, thus, its exports to the EU. As a result, the EU would become more dependent on imports from outside Europe. The resulting supply gap would be partly filled with additional gas from the Russian Federation. Due to a slightly increasing gas demand in the EU in 2025, the Russian market share would remain stable at 31%. Furthermore, a minor amount of natural gas (11 bcm in 2025) would be imported via the SGC from Azerbaijan. Finally, LNG would be the main source of gas that would replace the declining European production. The LNG import in the EU would increase from a market share of 9% in 2016 to 20% in 2025. The more heterogeneous imports, particularly evoked by additional LNG supply, increase the diversity of natural gas supply on an aggregated EU level. Hence, in 2025, the HHI of an integrated EU natural gas market would be at 1430 even lower than today' value.

The supply mix in Figure 5.3 can be sufficiently realized with the existing, planned and already financed (FID) EU natural gas infrastructure. Only some additional investment is identified within the EU[24]: (1) a pipeline in the Balkan region that allows the import of gas that arrives in Turkey via Turk Stream, (2) a pipeline that connects the Baltic States and Poland and (3) a pipeline that distributes the additional vol-

[22]However, also without Nord Stream 2 the Russian market share and thus the HHI of both countries would increase, as shown in a sensitivity in which Nord Stream 2 is prohibited in Appendix D.4.

[23]For more details on the economics of Nord Stream 2, see Hecking et al. (2016).

[24]COLUMBUS identifies demand for investment on a cross border or inter-connector level. It does not consider bottlenecks within a country.

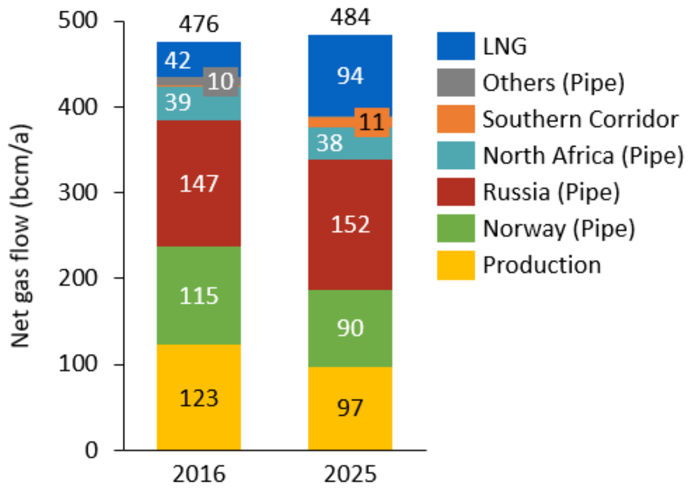

Figure 5.3.: EU gas supply mix in the Reference Scenario

umes of Russian gas that is supplied via Nord Stream 2 to Germany[25]. However, outside the EU, the model identifies a demand for the two large Russian pipeline projects: Turk Stream and Nord Stream 2. The demand for investment in the two Russian export pipelines is driven by the economic rationale to bypass Ukraine and avoid high transit fees, which are assumed to stay at the current level[26]. There results show no need for additional LNG facilities. While the western states benefit from their sufficient LNG infrastructure and imports from overseas, the eastern states benefit from their close distance to the Russian Federation and the supply via pipeline.

The ACER Target Scenario

In the ACER Target Scenario, an achievement of ACER's HHI score is mandatory by 2025. In order for this to be possible, Russian LTCs for at least some of the EU member states[27] need to be relaxed, as their continued enforcement up to 2025 and beyond would make a reduction of the HHI below 2000 impossible. After the relaxation of the LTCs, all countries considered (i.e., the western as well as the eastern states) fulfill the HHI of max. 2000.

[25]The so-called EUGAL pipeline that partly distributes the gas supplied via Nord Stream 2.
[26]For a more detailed analysis on the Ukrainian transit tariffs as well as the rationale for Nord Stream 2 at lower tariffs can be seen Hecking et al. (2016).
[27]These include the Czech Republic, Slovakia, Austria and Germany.

The satisfaction of the HHI threshold changes the entire European supply mix significantly compared to the Reference Scenario, mainly due to the detriment of Russian gas supply volumes. As shown in Figure 5.4, the Russian supply would be reduced to 97 bcm in 2025, 55 bcm less than in the Reference Scenario. While the domestic European gas supply from the EU member states as well as from Norway remain more or less stable, the LNG supply would increase by 43 bcm to 138 bcm. Due to its high supply costs, natural gas imports via the SGC from Azerbaijan would increase only slightly.

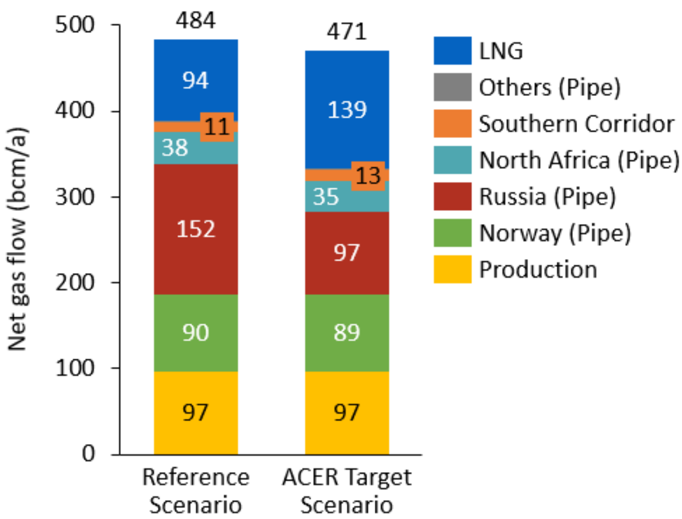

Figure 5.4.: Scenario comparison of EU gas supply mix in 2025

On a member state level, it becomes clear that there would be a dramatic change in gas flows. A strong drop in Russian gas supply from the east would be replaced by a surge of LNG supply predominantly imported in western Europe. The declining gas production of the Dutch Groningen gas field would also be compensated by higher LNG imports. In comparison to the Reference Scenario, the Netherlands would become a net re-exporter to Germany in the ACER Target Scenario. The same applies for Belgium and Poland, who would both re-export LNG to Germany. Hence, Germany would strongly reduce its share of Russian gas, making Nord Stream 2 superfluous. As a result, the role of Germany as a European transit country would be lower – with 44 bcm instead of 70 bcm re-exports – in 2025. However, gas transits from Russia would be partly replaced by gas transits from Germany's western border to eastern and southern European countries. This would enable the diversification of the eastern European markets. Furthermore, markets with access to the sea, such as Poland or the Baltics, would increase their LNG imports. The same applies for Greece and Italy. These two countries, together with Bulgaria, would also have slightly higher imports via the SGC. Hence, even when the high cost imports via the SGC are limited in volume, they would contribute in terms of diversification to some EU member states such as, in particular, the smaller gas markets in the Balkan region.

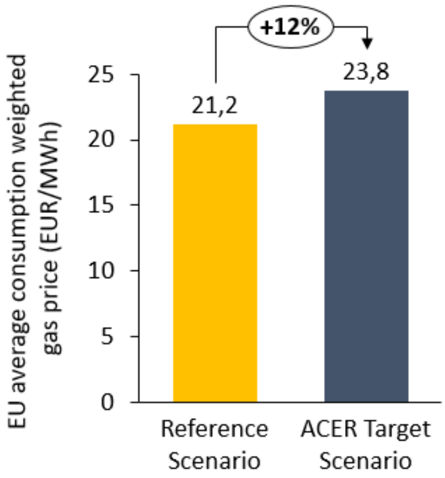

Figure 5.5.: Scenario comparison of EU gas prices

While the impact of ACER's diversification targets on demand for additional investment is only minor, its general impact on prices and consumer surplus is relevant. Figure 5.5 shows the effects of the realization of the ACER targets on natural gas prices. The implementation of the HHI threshold on a member-state level would lead to a price increase of the EU average consumption weighted gas price of 12% compared to a scenario without any diversification constraint. In terms of consumer surplus, this means a loss of 13 billion Euro within the EU in 2025. In particular, eastern member states that are closely located to Russia and already dependent on Russian supply today would suffer from higher natural gas prices. While prices in eastern European countries would increase by an average of 17.5%, prices in western European countries would rise by around 10.9%. Hence, the main driver for higher prices and the resulting loss of consumer surplus is not the additional demand for infrastructure but rather the replacement of lower-cost Russian gas supply with other sources, in particular LNG.

5.4. Conclusion & Further Research

The chapter analyzed ACER's diversification metric, the Herfindahl Hirschmann Index (HHI) and its impact on the EU natural gas market. First, ACER's definition of the relevant market, which is crucial for the interpretation of the concentration index HHI, is qualitatively discussed based on existing literature. ACER defines the relevant market on a national basis; however, it is argued that the definition is not sufficient because it neglects both the internal EU gas market as well as the presence of outside options. When assuming the internal EU gas market as the relevant market, the HHI score of at max 2000 would already be reached today. Second, a realization the HHI, as defined by ACER, was analyzed with a quantitative simulation model. The focus of the analysis is on the year 2025. Within two scenarios, it was shown that the adherence of the maximum HHI is theoretically possible on a national level. However, the simulation results show that the reduction of the HHI below 2000 on a member state level and the associated diversification would have a strong implication on gas flows as well as on the economics within the EU. On the one hand, eastern natural gas flows, e.g, from the Russian Federation would be replaced by western natural gas flows, e.g., from LNG imports. As a consequence, Russia would have to reduce its gas supply by around one third by 2025. On the other hand, due to the ban on low-cost Russian gas, the diversification would result in higher European natural gas prices and hence a loss in consumer surplus of 13 billion Euro. Due to the dependence of, in particular, eastern European states on Russian gas, prices and consumer surplus of these states would suffer more (+17.5%) compared to western European states (+10.9%).

Albeit the analysis has clearly identified the shortcomings of ACER's definiton of the HHI and how it is applied to monitor whether the EU natural gas market is well-functioning, there are namely two aspects identified that could be addressed by further research: First, although ACER's definition of the relevant market underrates the progress of the internal EU gas market, the application of the HHI on the entire EU may overrate the current level of gas market integration. In a subsequent analysis, the EU market could be separated into regional clusters of already well-integrated EU member states. The clusters would represent the relevant market that could be evaluated by concentration indices like the HHI. Second, the analysis focussed on ACER's health metric HHI only. Further research could focus on the RSI as the main indicator to monitor if the EU gas market is well functioning.

Notwithstanding the above mentioned further research, a recommendation of this analysis is that the EU should further focus on the development of its internal gas market and evaluate diversification on a more comprehensive level than of a national one. If the EU gas markets would be further integrated, gas could flow more freely between the member states. As such, an outside option would be made available for each member state, which would allow for supply from its neighboring market in the event a supplier would try to exert market power.

A. Supplementary Material for Chapter 2

A.1. Welfare Implications of a Quota

Proposition A.1. *The imposition of a strictly positive quota $L > 0$ does not increase the total welfare.*

Proof. A quota would not increase the welfare if $\frac{\partial W}{\partial L}|_{L=0} \leq 0$ holds. Therefore, we consider the first order condition of welfare optimization:

$$\frac{\partial W}{\partial L} = \left(1 + \frac{\partial q_D^*}{\partial L}\right) p\left(q_D^* + L\right) - C_D^{'}\left(q_D^*\right) \cdot \frac{\partial q_D^*}{\partial L} - C_F^{'}\left(L\right). \tag{A.1}$$

This yields:

$$\left.\frac{\partial W}{\partial L}\right|_{L=0} = p\left(q_D^*\right) + \left(p\left(q_D^*\right) - C_D^{'}\left(q_D^*\right)\right) \cdot \frac{\partial q_D^*}{\partial L} - C_F^{'}\left(0\right). \tag{A.2}$$

The second term is zero or negative because:

- $\left(p\left(q_D^*\right) - C_D^{'}\left(q_D^*\right)\right) \geq 0$ due to the profit optimization of the dominant supplier (she would not bid below marginal costs)
- $\frac{\partial q_D^*}{\partial L} < 0$ (cf. proof for Proposition 2.1)

Therefore, it follows:

$$\left.\frac{\partial W}{\partial L}\right|_{L=0} \leq p\left(q_D^*\right) - C_F^{'}\left(0\right). \tag{A.3}$$

For $C_F^{'}\left(0\right) \geq p\left(q_D^*\right)$, it holds true that the welfare does not increase:

$$\left.\frac{\partial W}{\partial L}\right|_{L=0} \leq 0. \tag{A.4}$$

□

Please note that the welfare strictly decreases for $C_F^{'}(0) > p\left(q_D^*\right)$.

B. Supplementary Material for Chapter 3

B.1. Model description

The COLUMBUS model applied in the paper allows for analysing inefficiencies, which might arise due to strategic behaviour of market players. The model code is derived using the maximisation problem of the different players (i.e. producers, exporters, regasifiers, etc.) in the global gas market. COLUMBUS optimises under the assumption of perfect competition the future development of production, transport and storage capacities as well as the dispatch of gas flows around the world. The model uses an inelastic demand and a piecewise-linear supply function representing consumption and production. Furthermore it can be extended to include a simulation of strategic behaviour of different players (e.g. producers) and analyse market power on the demand side, too.

The following model description is based on Hecking and Panke (2012). COLUMBUS is a spatial model consisting of vertices and edges. Vertices can be either sources (production facilities) or sinks (demand). Pipelines and LNG shipping routes are connected with edges. Table B.1 gives an overview of all sets, parameters and variables in the model.

Notation: Sets, Variables and Parameters

Table B.1.: Sets, Dual Variables, Parameters

1. Sets	
$n, n1 \in N$	all model nodes
$c \in C$	cost levels (steps of piecewise linear supply function)
$t \in T$	months
$y \in Y$	years
$p \in P \in N$	producer / production regions
$e \in E \in N$	exporter / trader
$d \in D \in N$	final customer / demand regions
$r \in R \in N$	regasifiers
$l \in L \in N$	liquefiers

Table B.1.: Sets, Dual Variables, Parameters

$s \in S \in N$	storage
2. Primal Variables	
$pr_{p,c,t}$	produced gas volumes
$fl_{e,n,n1,t}$	physical gas flows
$tr_{e,d,t}$	traded gas volumes
$st_{s,t}$	gas stock in storage
$si_{s,t}$	injected gas volumes in stroage
$sd_{s,t}$	depleted gas volumes from storage
$dr_{p,c,y}$	depleted resources
$ip_{p,c,y}$	annual investment into production capacity
$it_{n,n1,y}$	annual investment into pipeline transport capacity
$is_{s,y}$	annual investment into storage capacity
$ilng_{y}$	annual investment into LNG transport capacity
$ir_{r,y}$	annual investment into regasification capacity
$il_{l,y}$	annual investment into liquefaction capacity
$mdo_{e,d,t}$	minimal delivery obligation
3. Dual Variables	
$\lambda_{p,c,t}$	marginal costs of physical gas supply by exporter e to node n in time period t
$\sigma_{s,t}$	(intertemporal) marginal costs of storage injection
$\alpha_{p,c,y}$	marginal value of resources in node n at cost level c in year y
$\beta_{d,t}$	marginal costs / price in node n in time period t
$\mu_{p,c,t}$	marginal benefit of an additional unit of production capacity
$\phi_{n,n1,t}$	marginal benefit of an additional unit of pipeline capacity
$\epsilon_{s,t}$	marginal benefit of an additional unit of storage capacity
$\psi_{s,t}$	marginal benefit of an additional unit of storage injection capacity
$\theta_{s,t}$	marginal benefit of an additional unit of storage depletion capacity
ι_{t}	marginal benefit of an additional unit of LNG transport capacity
$\gamma_{r,t}$	marginal benefit of an additional unit of regasification capacity
$\zeta_{l,t}$	marginal benefit of an additional unit of liquefaction capacity
$\chi_{e,d,t}$	marginal costs of delivery obligation
4. Parameters	
$dem_{d,t}$	final customer's demand for natural gas
$cap_{n,t/n,n1,t/n,c,t}$	monthly infrastructure capacity
$res_{n,c,y}$	maximum resources
$trc_{n,n1,t}$	transport costs

Table B.1.: Sets, Dual Variables, Parameters

$prc_{n,c,t}$	production costs
$opc_{n,t}$	operating costs
$inc_{n,y/n,n1,y/n,c,y}$	investment costs
$dist_{n,n1}$	distance between node n and node n1 in km
$LNGcap$	initial LNG capacity
$speed$	speed of LNG tankers in km/h
cf_s	conversion factor used for storage inj. and depl. capacity
elt	economic life time of an asset
$slope_{d,t}$	slope of the linear demand function in node d
cv_e	conjectural function of exporter e; market power level

The time structure of the model is defined by a set $T \subset N$ of points in time (months)[1], which is flexible designed for adaption by a respective user. Any year (y) until 2040 can be simulated with up to twelve month per year.

In the following the optimisation problems of the different players modelled in COLUMBUS as well as their corresponding first-order optimality conditions are outlined. The first-order conditions are combined with the market clearing conditions in order to form the partial equilibrium model.

B.1.1. The Exporter's Problem

First of all, exporters $e \in E$ are defined as a trading unit associated with one or more production regions $p \in P_e$. With respect to the assumed profit maximising behavior, an exporter buys gas from the different production regions and sells the gas ($tr_{e,d,t}$) on the wholesale markets of the demand nodes $d \in D$ over the modelled time period $t \in T$. The exporter's payoff function is defined in equation B.1, where $\lambda_{e,d,t}$ corresponds to the exporter's costs of physical gas delivery to demand node d and $\beta_{e,d,t}$ is the market price at the demand node. Exporters may either act as price takers or as potential executors of market power. If the exporter can exert market power it observes the linear inverse demand function, otherwise it observes market price directly. Conjectural variation parameter, cv_e, is used to express the exporters

[1]In the current paper, only annual results are represented for the sake of simplicity.

those have market power.

$$\begin{aligned}
&\max_{tr_{e,d,t}} \prod_{eI}(tr_{e,d,t}) \\
&= \sum_{t\in T}\sum_{d\in D}\Big((1-cv_e)\cdot\beta_{e,d,t} + cv_e\cdot\beta_{e,d,t}(\sum_{e\in E} tr_{e,d,t}) - \lambda_{e,d,t}\Big)\cdot tr_{e,d,t}, \qquad \text{(B.1)}\\
&tr_{e,d,t} \geq 0
\end{aligned}$$

Moreover, in case of a Long-term contract (LTC) between the exporter and the improting region, the trade flows between them have a lower bound, i.e., a minimal delivery obligation $mdo_{e,d,t}$. The LTCs are taken in to account in the following constraint.

$$\sum_{t\in T} tr_{e,d,t} - mdo_{e,d,t} \geq 0 \qquad \forall e,d,t \qquad (\chi_{e,d,t}). \tag{B.2}$$

However, in reality an exporter faces the problem of how to minimise transport costs when selling natural gas on a wholesale market with physical delivery by choosing the cost-minimising transport flows $fl_{e,n,n1,t}$. COLUMBUS modells this as a separate optimisation problem as shown in equation B.3, where $opc_{n,t}$ reflects the costs of regasifying a unit of natural gas if n is a regasification node $[r(n)]$, while $trc_{n,n1,t}$ is denoted as the short-run marginal LNG transport costs from node n to node $n1$.

$$\max_{fl_{e,n,n1,t}} \prod_{e\Pi}(fl_{e,n,n1,t}) = \sum_{t\in T}(\lambda_{e,n1,t} - \lambda_{e,n,t} - trc_{n,n1,t} - opc_{n,t})\cdot fl_{e,n,n1,t} \tag{B.3}$$

Further physical transport constraint within the optimisation problem are formulated in equation B.4 (pipeline capacity), equation B.5 (liquefication capacity) and equation B.6 (regasification capacity).

$$cap_{n,n1,t} + \sum_{y\in Y_t} it_{n,n1,y} - \sum_{e\in E} fl_{e,n,n1,t} \geq 0 \qquad \forall n,n1,t \qquad (\phi_{n,n1,t}). \tag{B.4}$$

$$cap_{l,t} + \sum_{y\in Y_t} il_{l,y} - \sum_{e\in E}\sum_{n\in N} fl_{e,n,l,t} \geq 0 \qquad \forall l,t \qquad (\zeta_{l,t}). \tag{B.5}$$

$$cap_{r,t} + \sum_{y\in Y_t} ir_{r,y} - \sum_{e\in E}\sum_{d\in D} fl_{e,r,d,t} \geq 0 \qquad \forall r,t \qquad (\gamma_{r,t}). \tag{B.6}$$

Additionally the limitation of available LNG transport capacity is defined with the constraints of average speed in km/h($speed$), distance between n and $n1$ as well as back in km and number of LNG tankers times their average size ($LNGcap$).

$$\begin{aligned} &\left(LNGcap + \sum_{y \in Y_t} ilng_y\right) \cdot 8760/12 \cdot speed \\ &- \sum_{e \in E} \sum_{l \in L} \sum_{r \in R} 2 \cdot (fl_{e,l,r,t} \cdot dist_{n,n1}) \geq 0 \qquad \forall t \qquad (\iota_t) \end{aligned} \tag{B.7}$$

B.1.2. The Producer's Problem

Next, every producer $p \in P$ is assumed to operate a single production region, where revenue is earned by selling gas from its production region to an exporter. The producer's payoff function $\prod_p pr_{p,c,t}, ip_{p,c,y}$ given below assumes that every producer maximises her profit, while acting as a price taker in the market.

$$\begin{aligned} \max_{\substack{pr_{p,c,t} \\ ip_{p,c,y}}} \prod\nolimits_p (pr_{p,c,t}, ip_{p,c,y}) = &\sum_{t \in T} \sum_{c \in C} (\lambda_{e,p,t} + pr_{c,p,t} - prc_{c,p,t} \cdot pr_{p,c,t}) \\ &+ \sum_{y \in Y} \sum_{c \in C} (inc_{c,p,y} \cdot ip_{p,c,y}) \end{aligned} \tag{B.8}$$

The set of feasible solutions for $pr_{p,c,t}$ is restricted to be non-negative, constrained to a maximum production capacities equation B.9 and restricted by a resource constraint equation B.10, respectively reformulated as equation B.11:

$$cap_{p,c,t} + \sum_{y \in Y_t} ip_{p,c,y} - pr_{p,c,t} \geq 0 \qquad \forall p, c, t \qquad (\mu_{p,c,t}) \tag{B.9}$$

$$res_{p,c,y} - dr_{p,c,y} \geq 0 \qquad \forall p, c, y \qquad (\alpha_{p,c,y}). \tag{B.10}$$

$$res_{p,c,y} - dr_{p,c,y-1} - \sum_{t \in T(y)} pr_{p,c,t} \geq 0 \qquad \forall p, c, y \qquad (\alpha_{p,c,y}). \tag{B.11}$$

B.1.3. The Transmission System Operator's Problem

A number of Transmission System Operators (TSO) are modelled as players in the natural gas market which is subject to regulation (e.g. price). Because short-run marginal transport costs $trc_{n,n1,t}$ cancel out, the pay-off function of the TSOs (equation B.12) is the result following constraint icluding the congestion rent ($\phi_{n,n1,t}$).

$$\max_{it_{n,n1,y}} \prod\nolimits_{TSO}(it_{n,n1,y}) = \sum_{t\in T}\Big[\phi_{n,n1,t}\cdot(cap_{n,n1,t}+\sum_{y\in Y_t} it_{n,n1,y})\Big]-\sum_{y\in Y}(inc_{n,n1,y}\cdot it_{n,n1,y}). \tag{B.12}$$

B.1.4. The Liquefier's Problem

Liquefiers $l\in L$ receive natural gas from exporters e, liquefy it and use LNG tankers to send the resulting LNG downstream to regasifiers $r\in R$. Thereby Liquefiers allocate liquefaction capacities to the traders and receive in return the sum of short-run variable liquefication costs $opc_{l,t}$ and the congestion rent $\zeta_{l,t}$, which is determined by the liquefication capacity restriction (equation B.5). The liquefiers maximise the profit function as shown in equation B.13.

$$\max_{il_{l,y}} \prod\nolimits_{l}(il_{l,y}) = \sum_{t\in T}\Big[\zeta_{l,t}\cdot(cap_{l,t}+\sum_{y\in Y_t} il_{l,y})\Big]-\sum_{y\in Y}(inc_{l,y}\cdot it_{l,y}). \tag{B.13}$$

B.1.5. The Regasifier's Problem

Regasifiers $r\in R$ receive LNG, regasify it and send the resulting natural gas to a demand node by the TSO of the respective pipeline. The optimisation problem (here L_r w.r.t. $ir_{r,y}$) is similar to the liquifier's one, also if the congestion rent is now denoted as $\gamma_{r,t}$ and is determined by the regasification capacity constraint (equation B.6). The respective profit function (equation B.14) is stated as:

$$\max_{ir_{r,y}} \prod\nolimits_{r}(ir_{r,y}) = \sum_{t\in T}\Big[\gamma_{r,t}\cdot(cap_{r,t}+\sum_{y\in Y_t} ir_{r,y})\Big]-\sum_{y\in Y}(inc_{r,y}\cdot ir_{r,y}). \tag{B.14}$$

B.1.6. The LNG Problem

Because no specific players within the LNG market are modelled, one virtual investor is assumed to invest in LNG transport capacities (i.e. LNG tankers), who is expected to behave perfectly competitive. Thereby, investments into additional capacity conitinue until marginal investment costs equal marginal benefits. The optimisation problem of investments in LNG is defined in equation B.15, where the congestion rent ι_y is determined by the LNG capacity restriction (equation B.7).

$$\max_{ilng_y} \prod\nolimits_{LNG}(ilng_y)$$
$$= \sum_{t \in T} \left[\iota_t \cdot 8760/12 \cdot speed \cdot (cap_t + \sum_{y \in Y_t} ilng_y) \right] - \sum_{y \in Y} (inc_y \cdot ilng_y). \tag{B.15}$$

B.1.7. The Storage Operator's Problem

Each storage facility, which is located in the respective demand region d, is operated by one storage operator $s \in S$, who maximizes her revenue by buying gas in off-peak periods at low prices and selling it during peak periods at high prices. Similar to the producer's problem each storage operator faces a dynamic optimisation problem (equation B.16), maximising the injection and depletion of natural gas as well as the annual investments ($is_{s,y}$), subject to some capacity constraints (equations B.17 to B.19).

$$\max_{\substack{si_{s,t}, sd_{s,t} \\ is_{s,y}}} \prod\nolimits_s (si_{s,t}, sd_{s,t}, is_{s,y}) = \sum_{t \in T} \beta_{d,t} (sd_{s,t} - si_{s,t}) - \sum_{y \in Y} (inc_{s,y} \cdot is_{s,y}) \tag{B.16}$$

$$cap_{s,t} + \sum_{y \in Y_t} is_{s,y} - st_{s,t} \geq 0 \quad \forall s, t \quad (\epsilon_{s,t}) \tag{B.17}$$
$$cfs \cdot (cap_{s,t} + \sum_{y \in Y_t} is_{s,y} - si_{s,t} \geq 0 \quad \forall s, t \quad (\rho_{s,t}) \tag{B.18}$$
$$cfs \cdot (cap_{s,t} + \sum_{y \in Y_t} is_{s,y} - si_{s,t} \geq 0 \quad \forall s, t \quad (\theta_{s,t}) \tag{B.19}$$

The motion of the stock ($st_{s,t}$) is defined as:

$$\Delta st_{s,t} = st_{s,t+1} - st_{s,t} = si_{s,t} - sd_{s,t} \qquad \forall s, t \qquad (\sigma_{s,t}) \tag{B.20}$$

B.1.8. Karush–Kuhn–Tucker(KKT) Conditions

The COLUMBUS model is based on profit optimization problems of the different players (exporters, producers, transmission system operators, liquefiers, regasifiers). Each profit optimization problem has corresponding first order conditions. Together with the market clearing conditions, the first order conditions define the model.

Exporters

$$-\beta_{d,t} + (cv_e + 1) \cdot \text{slope}_{d,t} \cdot tr_{e,d,t} - \chi_{e,d,t} + \lambda_{e,d,t} \geq 0 \quad \perp \quad tr_{e,d,t} \geq 0 \qquad \forall e, d, t. \tag{B.21}$$

$$- \lambda_{e,n,n1,t} + \lambda_{e,n,t} + trc_{n,n1,t} + trc_{n,n1,t} + opc_{n,t} + \phi_{n,n1,t} + \zeta_{l,t} + \gamma_{r,t} + \iota_t \cdot 2 \cdot dist_{l,r} \geq 0 \quad \perp \quad fl_{e,n,n1,t} \geq 0 \qquad \forall e, n, n1, t. \tag{B.22}$$

Producers

$$-\lambda_{e,p,t} + prc_{p,c,t} + \sum_{y \in Y_t} \alpha_{p,c,y} + \mu_{p,c,t} \geq 0 \quad \perp \quad pr_{p,c,t} \geq 0 \qquad \forall p, c, t \tag{B.23}$$

$$\alpha_{p,c,y+1} - \alpha_{p,c,y} \leq 0 \quad \perp \quad dr_{p,c,y} \geq 0 \qquad \forall p, c, y \tag{B.24}$$

$$in_{c,p,y} - \sum_{t \in T(y)} \mu_{p,c,y} \geq 0 \quad \perp \quad ip_{p,c,y} \geq 0 \qquad \forall p, c, y \tag{B.25}$$

Transmission System Operators

$$inc_{n,n1,y} - \sum_{t \in T_y} \phi_{n,n1,t} \geq 0 \quad \perp \quad it_{n,n1,y} \geq 0 \qquad \forall n, n1, y. \tag{B.26}$$

Liquefiers

$$inc_{l,y} - \sum_{t \in T_y} \zeta_{l,t} \geq 0 \quad \perp \quad il_{l,y} \geq 0 \qquad \forall l, y. \tag{B.27}$$

Regasifiers

$$inc_{r,y} - \sum_{t \in T_y} \gamma_{r,t} \geq 0 \quad \perp \quad ir_{r,y} \geq 0 \qquad \forall r, y. \tag{B.28}$$

LNG Shippers

$$inc_y - \sum_{t \in T_y} (\iota_t \cdot 8760/12 \cdot speed) \geq 0 \quad \perp \quad ilng_y \geq 0 \qquad \forall y. \tag{B.29}$$

Storage

$$-\beta_{d,t} + \sigma_{s,t} + \theta_{s,t} \geq 0 \quad \perp \quad sd_{s,t} \geq 0 \qquad \forall s,t \tag{B.30}$$

$$-\sigma_{s,t} + \beta_{s,t} + \rho_{s,t} \geq 0 \quad \perp \quad si_{s,t} \geq 0 \qquad \forall s,t \tag{B.31}$$

$$\epsilon_{s,t} = \Delta\sigma_{s,t} = \sigma_{s,t+1} - \sigma_{s,t} \leq 0 \quad \perp \quad st_{s,t} \leq 0 \qquad \forall s,t \tag{B.32}$$

$$in_{c,s} - \sum_{t\in T_y} [\epsilon_{s,t} + cf_{s,t} \cdot (\rho_s, t + \theta_{s,t})] \geq 0 \quad \perp \quad is_{s,y} \geq 0 \qquad \forall s,y \tag{B.33}$$

Market Clearing Conditions

The market clearing conditions are given by the following equations:

$$\sum_{c\in C} pr_{p,c,t} - tr_{e,d,t} + \sum_{n1\in(n1,n)\in A} fl_{e,n1,n,t} - \sum_{n1\in(n,n1)\in A} fl_{e,n,n1,t} = 0 \quad \perp \quad \lambda_{e,n,t} \quad free \qquad \forall e,n,t. \tag{B.34}$$

$$\sum_{e\in E} tr_{e,d,t} + mdo_{e,d,t} + sd_{s,t} + si_{s,t} - dem_{d,t} = 0 \quad \perp \quad \beta_{d,t} \quad \text{free} \qquad \forall d,t. \tag{B.35}$$

Equation (B.34) must be fulfilled for each exporter $e \in E$ that is active at the node $n \in N_e$. Additionally, the equation ensures equality of traded volumes and physical flows. Equation (B.35) defines the gas balance at demand nodes d in month t making sure that the final demand is met.

Table B.2.: Countries, Continents, Nodes

Demand Node	**Production Node**	**Liquification Node**	**Regasification Node**	**Storage Node**	**Country/Country Groups**	**Continent**
AE_Prod_umm	AE_Prod_umm	AE_Liq_das	AE_Regas_dubai		United Arab Emirates	Middle East
AO_Prod_angoff	AO_Prod_angoff	AO_Liq_luanda			Angola	North Africa
AR_Prod_neuq	AR_Prod_neuq		AR_Regas_bahi	AR_Prod_neuq	Argentina	Latin America
AT_Cons_oest				AT_Cons_west	Austria	Europe
AU_Prod_nws	AU_Prod_nws	AU_Liq_burr		AU_Prod_nws	Australia	Asia and Oceania
AZ_cons_azer	AZ_Prod_others			AZ_cons_azer	Azerbaijan	CIS
BALT_Cons_balt			BALT_regas_balt	BALT_Cons_balt	Baltics	Europe
BD_Cons_bangl					Bangladesh	Asia and Oceania
BE_Cons_belg			BE_regas_zee	BE_Cons_belg	Belgium	Euorpe
BG_Cons_bulg	BG_Prod_others			BG_Cons_bulg	Bulgaria	Europe
BH_Cons_bahr					Bahrain	Middle East
BN_Prod_bruoff	BN_Prod_bruoff	BN_Liq_lumut			Brunei	Asia and Oceania
BO_Prod_tarija	BO_Prod_tarija				Bolivia	Latin America
BR_Cons_brazil			BR_Regas_suape		Brazil	Latin America
BY_Cons_bela				BY_Cons_bela	Belarus	CIS
CA_Prod_alber	CA_Prod_alber	CA_Liq_kiti	CA_Regas_canap	CA_Prod_alber	Canada	North America
CH_Cons_swi					Switzerland	Europe
CL_Cons_chile			CL_Regas_santi		Chile	Latin America
CN_Cons_china	CN_Cons_tarim		CN_Regas_fuji	CN_Cons_china	China	Asia and Oceania
	CN_Prod_saich				China	Asia and Oceania
CO_Cons_columb					Columbia	Latin America
CY_Prod_cyp	CY_Prod_others	CY_Liq_cyp			Cyprus	Europe
CZ_Cons_czec				CZ_Cons_czec	Czechia	Europe
DE_Cons_ger			DE_Regas_wilh	DE_Cons_ger	Germany	Europe

Table B.2.: Countries, Continents, Nodes

DE_cons_nord					Germany	Europe
DE_cons_south					Germany	Europe
DK_Cons_denm	DK_Prod_greenl	DK_Liq_greenl		DK_Cons_denm	Denmark	Europe
	DK_Prod_tyra				Denmark	Europe
DO_Cons_dom			DO_regas_andr		Dominica	Latin America
DZ_Prod_hassi	DZ_Prod_hassi	DZ_Liq_arzew			Algeria	Africa
EG_Prod_nildel	EG_Prod_nildel	EG_Liq_dami	EG_Regas_egy		Egypt	Africa
ES_Cons_spa			ES_Regas_barc	ES_Cons_spa	Spain	Europe
FI_Cons_fin					Finland	Europe
FR_Cons_fr			FR_Regas_fos	FR_Cons_fr	France	Europe
GH_Cons_ghana					Ghana	Africa
GO_Cons_geo					Georgia	CIS
GQ_Prod_alba	GQ_Prod_alba	GQ_Liq_bioko			Equatorial Guinea	Africa
GR_Cons_grec			GR_Regas_revi		Greece	Europe
HU_Cons_hun				HU_Cons_hun	Hungary	Europe
ID_Prod_badak	ID_Prod_badak	ID_Liq_bonta			Indonesia	Asia and Oceania
IE_Cons_ire				IE_Cons_ire	Ireland	Europe
IN_Cons_india	IN_Cons_india		IN_Regas_dahej		India	Asia and Oceania
IQ_Prod_alanf	IQ_Prod_alanf				Iraq	Middle East
IR_Prod_sopa	IR_Prod_sopa	IR_Liq_assa			Iran	Middle East
IT_Cons_ita			IT_Regas_spez	IT_Cons_ita	Italy	Europe
JP_Cons_japan			JP_Regas_higa	JP_Cons_japan	Japan	Asia and Oceania
KR_Cons_korea			KR_Regas_inch		Korea	Asia and Oceania
KW_Cons_kuw			KW_Regas_kuw		Kuwait	Middle East
KZ_Prod_karach	KZ_Prod_karach			KZ_Prod_karach	Kazakhstan	CIS

Table B.2.: Countries, Continents, Nodes

LY_Prod_wafa	LY_Prod_wafa	LY_Liq_marsa			Lybia	Africa
MA_Cons_maroc					Morocco	Africa
MD_Cons_mol					Moldavia	Europe
MM_Prod_myaoff	MM_Prod_myaoff				Myanmar	Asia and Oceania
MX_Cons_mex	MX_Cons_mex		MX_Regas_alta		Mexico	Latin America
MY_Prod_maloff	MY_Prod_maloff	MY_Liq_bintu	MY_Regas_mal		Malaysia	Asia and Oceania
NE_Cons_neas	NE_Prod_isra		NE_Liq_isra		Niger	Middle East
NG_Prod_nigdel	NG_Prod_nigdel	NG_Liq_bonny			Nigeria	Africa
NL_Prod_gro	NL_Prod_gro		NL_Regas_rott	NL_Prod_gro	Netherlands	Europe
NO_Cons_norw	NO_Prod_nobar	NO_Liq_snohv			Norway	Europe
	NO_Prod_nosea				Norway	Europe
OM_Prod_saih	OM_Prod_saih	OM_Liq_qalhat			Oman	Middle East
PE_Prod_cam	PE_Prod_cam	PE_Liq_pacing			Peru	Latin America
PK_Cons_paki					Pakistan	Asia and Oceania
PL_Cons_pol	PL_Cons_pol		PL_Regas_swin	PL_Cons_pol	Poland	Europe
PT_Cons_port			PT_Regas_sin		Portugal	Europe
QA_Prod_nofi	QA_Prod_nofi	QA_Liq_ras			Qatar	Middle East
RO_Cons_rum	RO_Prod_others			RO_Cons_rum	Romania	Europe
RU_Prod_irku	RU_Prod_irku			RU_Prod_irku	Russia	CIS
	RU_Prod_rusbar				Russia	CIS
	RU_Prod_sahka	RU_Liq_sahlng			Russia	CIS
	RU_Prod_westsi				Russia	CIS
		RU_Liq_murma			Russia	CIS
RU_Cons_komi				RU_Cons_komi	Russia	CIS
RU_Cons_wour				RU_Cons_wour	Russia	CIS

Table B.2.: Countries, Continents, Nodes

SA_Prod_saudi	SA_Prod_saudi				Saudi Arabia	Middle East
SE_Cons_swe				SE_Cons_swe	Sweden	Europe
SG_Cons_singa			SG_Regas_silng		Singapore	Asia and Oceania
SI_Cons_slow					Slovenia	Europe
SK_Cons_slova				SK_Cons_slova	Slovakia	Europe
SY_Cons_syr	SY_Prod_syr				Syrian Arab Republic	Middle East
TH_Cons_thai			TH_Regas_thai		Thailand	Asia and Oceania
TM_Prod_amu	TM_Prod_amu				Turkmenistan	CIS
TN_Cons_tunis					Tunisia	Africa
TR_Cons_tur		TR_Liq_tur	TR_Regas_marma	TR_Cons_tur	Turkey	Europe
TT_Prod_dolph	TT_Prod_dolph	TT_Liq_atlng	TT_Regas_atlng		Trinidad and Tobago	Latin Amercia
TW_Cons_taiw			TW_Regas_yung		Taiwan	Asia and Oceania
UA_Cons_ukr	UA_Prod_others			UA_Cons_ukr	Ukraine	CIS
UK_Cons_gbr	UK_Prod_gbns		UK_Regas_milf	UK_Cons_gbr	Great Britain	Europe
US_Cons_west	US_Prod_alas	US_Liq_kenai	US_Regas_baja	US_Cons_west	United States of America	North America
US_Cons_east		US_Liq_gom	US_Regas_cove	US_Cons_east	United States of America	North America
US_Prod_henry	US_Prod_henry		US_Regas_lake	US_Prod_henry	United States of America	North America
UZ_Prod_buhk	UZ_Prod_buhk			UZ_Prod_buhk	Uzbekistan	CIS
VE_Prod_paria	VE_Prod_paria	VE_Liq_sucre			Venezuela	Latin America
YE_Prod_marib	YE_Prod_marib	YE_Liq_balhaf			Yemen	Middle East
YUGO_Cons_yugo				YUGO_Cons_yugo	former Yugoslavia	Europe

C. Supplementary Material for Chapter 4

C.1. Model description

Please see the model description in Appendix B.1.

C.2. Model Extensions

Equation (B.21) defines the first-order conditions of the exporter's problem[1]. This problem is re-formulated to optimize profits of exporters that sell volumes to a transit country with the transit country's conjectural variation cv_{tr} and the slope of the final demand region with the function $slope_{dem,t}$[2]:

$$-\beta_{d,t} + (cv_e + 1) \cdot (2 + cv_{tr}) \cdot slope_{dem,t} \cdot tr_{e,d,t} - \chi_{e,d,t} + \lambda_{e,d,t} \geq 0 \\ \perp tr_{e,d,t} \geq 0 \ \forall e, d, t \tag{C.1}$$

Equation (C.1) has the structure of equation (4.8). The transit country can be modeled as competitive (conjectural variation $cv_{tr} = -1$) or as a Cournot player (conjectural variation $cv_{tr} = 0$). The exporters that are supplying to a final market (including the transit country itself) have still first-order conditions of the form of equation (B.21).

Furthermore, the market clearing conditions given by equations (B.34) and (B.35) need to be extended. The volumes bought by the transit country $transit_t$ need to be included in those market clearing constraints for the nodes at the border of the transit country where it buys the transit volumes $n \in N_{TR}$:

[1]Growitsch et al. (2014) use a different convention of conjectural variations. This explains the difference between equation (11) in Growitsch et al. (2014) and equation (B.21).

[2]In the study at hand this is in particular the slope of the linear demand function of the EU market which is modeled in two regions. A more detailed description of the regions is given in Section 4.4.2. It is based on each country's linear demand function that are aggregated for the respective EU regions. The parameters of the EU demand functions determine the demand function for Turkish transit gas.

$$\sum_{c \in C} pr_{p,c,t} + transit_t - tr_{e,d,t} + \sum_{n1 \in (n1,n) \in A} fl_{e,n1,n,t} - \sum_{n1 \in (n,n1) \in A} fl_{e,n,n1,t} = 0 \quad \perp \lambda_{e,n,t} \text{ free } \forall e, n \in N_{TR}, t \tag{C.2}$$

The volumes bought by the transit country $transit_t$ are included in the second market clearing constraint as follows:

$$\sum_{e \in E} tr_{e,d,t} + sd_{s,t} - si_{s,t} - transit_t = 0 \perp \beta_{d,t} \text{ free } \forall d, t \tag{C.3}$$

C.3. Scenarios and Data sources

Table C.1.: Data and sources

Data	
Reference demand	Natural Gas Information 2017 (IEA, 2017b), Medium-Term Gas Market Report 2015 (IEA, 2015b), World Energy Outlook 2015 (NPS) (IEA, 2015a)
Price elasticities	Growitsch et al. (2014) and Egging et al. (2010)
Reference price	Based on TTF 2014
Production costs	Hecking et al. (2016), Seeliger (2006) and Aguilera et al. (2009)
Existing pipeline infrastructure	Ten Year Network Development Plan (ENTSOG, 2015)
LNG facilities	Capacity Map GIE (2015), LNG Industry Report GIIGNL (2016)
Storage facilities	Gas Storage Map GIE (2015), Natural Gas Information 2017 (IEA, 2017b)
Transportation costs	ACER Market Report 2014 ACER (2015b), Interfax (2015) and Pirani and Yafimava (2016)

Table C.2.: Scenario Overview

Number	Section	Upstream Sector	Turkish Behavior	Further Scenario Characteristics
1.1	Section 4.5.1	oligopolistic	competitive	-
1.2	Section 4.5.1	oligopolistic	oligopolistic	-
2.1	Section 4.5.2	competitive	competitive	-
2.2	Section 4.5.2	competitive	oligopolistic	-
A.1	Appendix C.4.2	oligopolistic	oligopolistic	transits from Azerbaijan and Turkmenistan via Russia possible
A.2	Appendix C.4.2	oligopolistic	oligopolistic	cartel of Russia, Azerbaijan and Turkmenistan

C.4. Sensitivity Analysis

C.4.1. Sensitivity on Turkish behavior in the oligopolistic setup

Figure C.1 illustrates how the Turkish transits (by origin) vary if the conjectural variation of Turkey is varied between -1 and 0 in the oligopolistic gas market configuration. It becomes clear that Israel and Iran are very sensitive on Turkey's transit behavior. If Turkey decides to exert market power, transits of these countries via Turkey to Europe are not competitive. Azerbaijan, however, is less sensitive because it is only able to export gas via Turkey (cf. Section C.4.2 for a sensitivity in which this assumption is relaxed).

Figure C.2 illustrates how the Turkish conjectural variation affects natural gas prices in SEE and NWE. While the SEE price is below the NWE price with competitive Turkish transits, this interrelation changes when market power is exerted: For conjectural variations larger than -0.8, the SEE price is larger than the NWE price.

The market situations with Turkish conjectural variations between -1 and 0 illustrated in the Figures C.1 and C.2 are cases in which both the EU and Turkey would benefit from the SGC, i.e. Turkey would earn some profits from transiting, and the EU would enjoy lower gas prices compared to a situation with double marginalization. Such a market situation could be e.g. the result of a bargaining process between gas consumers and the transit country (similar to the bargaining between upstream producers and the transit country mentioned in Section 4.2). However, it is important to note that such a bargaining solution could become obsolete if a competitive up-

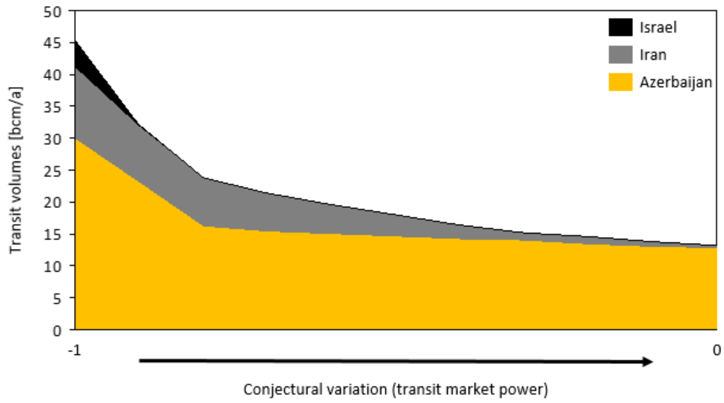

Figure C.1.: Turkish gas transits into the EU per source in dependence on Turkish behavior in 2030

stream market structure is assumed instead of an oligopolistic market because fewer volumes would pass through the SGC in the competitive setup.

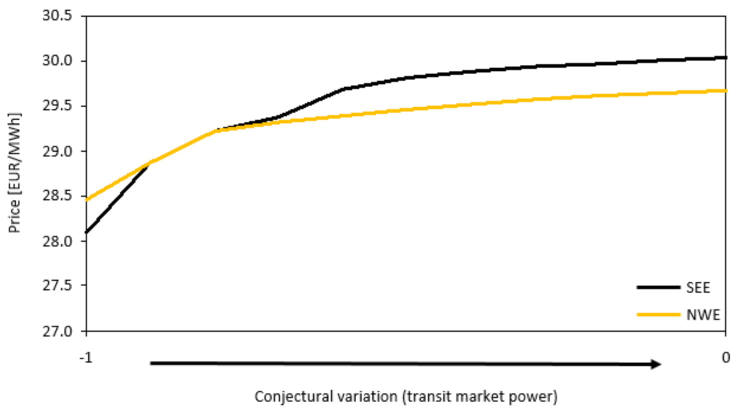

Figure C.2.: Natural gas price in SEE and NWE in dependence on Turkish behavior in 2030

C.4.2. Caspian Gas via Russia in the Oligopolistic Setup

In Section 4.5, it was assumed that Azerbaijan would be able to deliver gas via Turkey only to reach the EU market. Besides the EU, Azerbaijan could solely sell its gas to Georgia or Turkey. However, the Turkish and Georgian demand for Azerbaijani gas is relatively small and accounted for only 8 bcm in 2015 (Pirani, 2016). Looking into the past, Azerbaijan delivered up to 2 bcm of gas to Russia in 2012 (Pirani, 2016). Since then supplies have declined to zero in 2015. As of 2016, Azerbaijan is even importing about 2 bcm/a from Russia.[3] The main reason is the increasing domestic demand and the underdeveloped production of the Shah Deniz field. This situation may change when the Shah Deniz stage 2 will come online. Then, Azerbaijan would be able again to export gas also to Russia or even via Russia into the EU.

The following sensitivities are implemented within an oligopolistic upstream market structure. Therefore, the results from Section 4.5.1 are the relevant reference to compare the sensitivities to. In a first sensitivity, it is assumed that Azerbaijan and also Turkmenistan are able to deliver gas competitively via Russia into the EU while Turkey is exerting transit market power. As a consequence, both countries would not deliver any gas via Turkey and total Turkish transits to the EU would only be at 6.7 bcm in 2030. As shown in Figure C.3, these 6.7 bcm of natural gas that would reach the EU are Iranian gas. Due to reduced competition in the first-stage oligopoly (SGC producers competing about the transits through Turkey) compared to a situation in which Azerbaijan and Turkmenistan are part of this oligopoly, the remaining SGC producers can exercise more market power when selling gas to Turkey. Hence, it becomes more profitable for Iran to export gas via Turkey to the EU. The EU, however, benefits from Azerbaijani and Turkmen gas supplies via Russia. While EU prices would be 1.5% (0.9%) lower in SEE (NWE) compared to the scenario "Turkish market power" without outside options of Azerbaijan and Turkmenistan, EU's consumer surplus would be 0.1 billion EUR higher. As can be seen in Figure C.3, due to lower natural gas transits, Turkey's profit would be 0.5 billion EUR if Azerbaijan and Turkmenistan can circumvent Turkey instead of previously 1.8 billion EUR. But because of lower European gas prices and stronger competition with Azerbaijan and Turkmenistan in its key markets, Russia would also lose 0.7 billion EUR revenues as well as 0.2 billion EUR of profits by allowing transits on its territory compared to the case in which Turkey exercises market power and no SGC producer can ship through Russia. Thus, a situation in which Russia would allow Azerbaijan and Turkmenistan to use its infrastructure to bring additional gas amounts into the EU seems to be not likely. Therefore, this is not a viable solution for a more competitive European upstream gas market.

Another possible scenario would be that Russia buys gas from Azerbaijan and Turkmenistan and resells it to the EU instead of allowing competitive transits - similar to Turkey's assumed behavior. However, it is questionable if double marginalization would be the appropriate approach to describe this setting, since Russia has a huge indigenous gas production with comparably low production costs. Hence, Azerbai-

[3] http://www.azernews.az/oil_and_gas/96768.html

jan and Turkmenistan are not in a good position to exert market power against the Russian exporter.[4] Therefore, the scenario in which Russia buys gas from Azerbaijan and Turkmenistan is modeled as a cartel situation in which the three countries offer their gas amounts jointly as one player[5]. Together, these countries are in a strong position to act strategically. Thus, compared to the scenario in which all SGC producers have to sell gas to an oligopolistic Turkey in order to deliver gas to European markets, gas prices are higher in both modeled EU market areas (SEE and NWE) by about 2.8%. This leads to an EU welfare loss of 1.8 billion EUR compared to the Turkish market power scenario with all SGC producers selling to Turkey. Nonetheless, as illustrated in Figure C.3, even if Russia and the Caspian producers Azerbaijan and Turkmenistan would form a cartel, still 5.7 bcm of mainly Iranian natural gas would reach the EU markets via Turkey. Turkey could earn 0.4 billion EUR of profits.

Concluding, if Azerbaijan und Turkmenistan can ship gas through Russia (either competitively or by cooperation forming a cartel with Russia), the volumes that Turkey could resell to Europe would be below the already financed TAP capacity of 10 bcm/a. Nevertheless, Turkey could still earn profits of 0.4-0.5 billion EUR from the transits.[6]

[4]Turkey, on the other hand, does not have many options to buy gas from different producers.

[5]For modeling a cartel the same modeling approach as in Egging et al. (2009) is chosen.

[6]In reality, it is possible that the Caspian countries and Russia could find a form of cooperation between competitive transits and the cartel. In principle, a transit problem can also be seen as a bargaining problem in which cooperation (cartel) and Cournot competition among the respective producers would be extreme outcomes (cf. the discussion in Section 4.2 about options to avoid double marginalization). However, both considered scenarios with respect to the relations between the Caspian countries and Russia have similar implications for the SGC, i.e. if Azerbaijan and Turkmenistan ship through Russia, the volumes coming through the SGC are diminished.

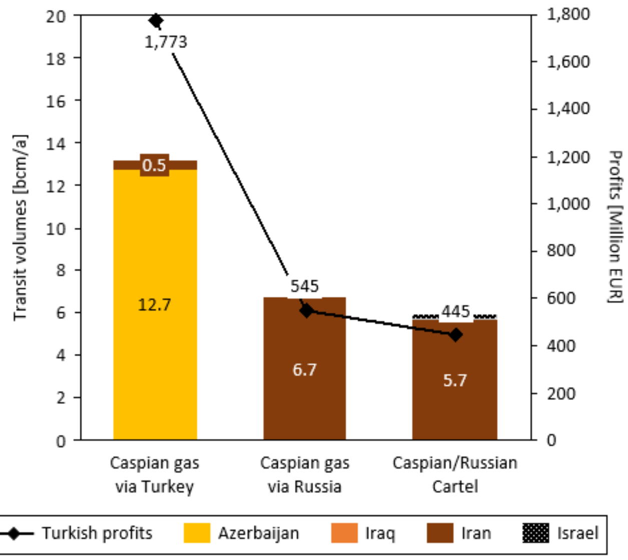

Figure C.3.: Turkish gas transits into the EU per source and Turkish profits in dependence on Caspian supply options in 2030

D. Supplementary Material for Chapter 5

D.1. Model description

Please see the model description in Appendix B.1.

D.2. COLUMBUS Model Extension

The supplier import constraint is extended by a maximum import limit $fl\_limit_{e,n,n1,t}$:

$$- \sum_{n1 \in (n,n1) \in A} fl_{e,n,n1,t} + fl\_limit_{e,n,n1,t} \geq 0 \quad \perp \quad \tau_{e,d,t} \geq 0 \qquad \forall e,d,t. \tag{D.1}$$

Equation B.21 defines optimal import decision. It is supplemented by the complementary $\tau_{e,d,t}$, of the equation D.1 that restricts the imports of the exporter e to a maximum limit.

$$\begin{aligned} -\beta_{d,t} + (cv_e + 1) \cdot \text{slope}_{d,t} \cdot tr_{e,d,t} - \chi_{e,d,t} + \lambda_{e,d,t} + \tau_{e,d,t} \geq 0 \\ \perp \quad tr_{e,d,t} \geq 0 \quad \forall e,d,t. \end{aligned} \tag{D.2}$$

D.3. Company shares of gas supplying countries

Table D.1 provides an overview of selected company shares that are applied to calculate a member states market concentration.

Table D.1.: Company structure of suppliers

Country	Sup 1	Sup 2	Sup 3	Sup 4	Sup 5	Sup 6	others
AT	100%						
DE	48%	23%	19%	7%	3%		
DK	33%	28%	18%	11%	10%		
HU	100%						
IE	45%	37%	20%				
IT	84%	9%	7%				
NL	100%						
PL	90%	10%					
RO	52%	41%	4%	3%			
NO	75%	13%	5%	3%	1%	1%	2%
AZ	100%						
DZ	100%						
LY	100%						
RU	100%						

D.4. Sensitivity: The Reference Scenario without Nord Stream 2

In the Reference Scenario a demand for investment in the Nord Stream 2 pipeline of 55 bcm/a is identified by the COLUMBUS model. The pipeline is a direct connection between the Russian Federation and Germany via the Baltic Sea, which will double the capacity of the existing pipeline Nord Stream. The identified demand for investment is approximately the project's technically available pipeline capacity. However, the project is controversially discussed. The European Commission and the USA are opponents of the project and argue that it would lead to a stronger European dependence on Russian gas which would counteract the European diversification strategy. The German government, by contrast, argues that the project is commercial.

In this sensitivity, the capacity of a direct connection between the Russian Federation and Germany is restricted to the existing pipeline Nord Stream and no investment in Nord Stream 2 is possible. The effects on the market concentration and hence the HHI are limited. Only Sweden would additionally surpass the HHI threshold of at most 2000, due to a change of the German and hence Danish import mix. However, the German market concentration would be only slightly lower because the absence of Nord Stream 2 would have an impact on the Germany re-exports or transits but not on the country's consumption. As a consequence thereof, the concentration of some of Germany's neighbouring countries would be slightly lower compared to the Reference Scenario with Nord Stream 2.

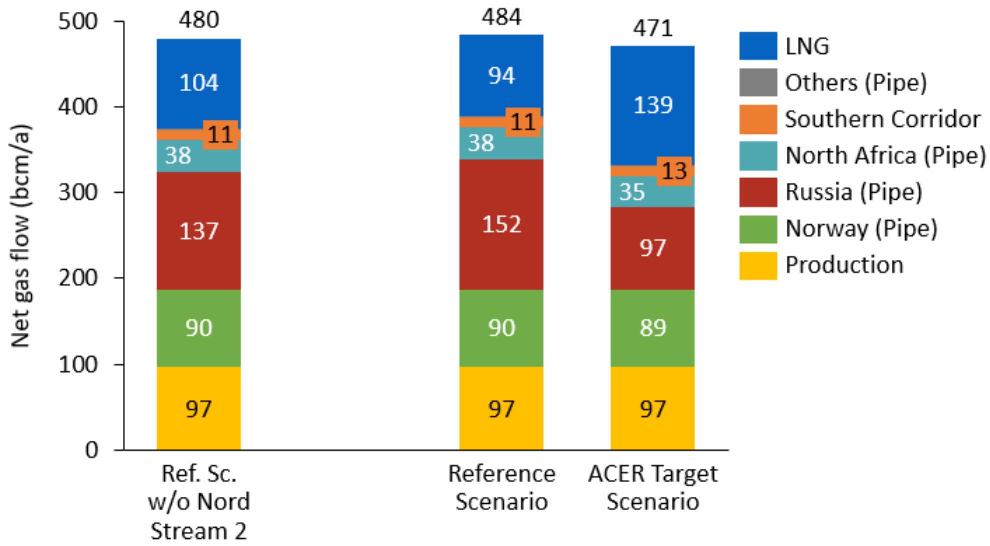

Figure D.1.: EU gas supply mix in the Reference Scenario without Nord Stream 2 in 2025

Figure D.1 depicts the EU supply mix in the considered scenario. It can be observed that without Nord Stream 2 the share of Russian gas in the EU would be still high, at 29 percent compared to 31 percent in the Reference Scenario. Hence, the lack of Nord Stream 2 would mainly result in a relocation of that supply route to the other Russian European pipeline routes, in particular the route via Ukraine. Thus, this underpins the hypothesis that Nord Stream 2 will mainly be used to replace the high cost Ukrainian Russian gas transits instead of bringing additional volumes to the European market in the medium term[1]. However, the minor reduction in Russian gas supply will be mainly intercepted by additional LNG imports. Hence, the high transport costs via Ukraine can be interpreted as a competitive disadvantage of Russian gas against LNG.

[1]In the long term it will be used to replace the more and more declining European gas production.

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Market power in natural gas markets
Natural gas market modelling

EDUCATION

01/2015 - 07/2019	**Institute of Energy Economics (EWI)** & **Department of Economics, University of Cologne** Doctoral Candidate in Economics under the Supervision of Prof. Dr. Marc Oliver Bettzüge and PD Dr. Dietmar Lindenberger
10/2012 - 11/2014	**Dresden University of Technology** Master of Science in Industrial Engineering
08/2014 - 10/2014	**Norwegian School of Economics** Studies Abroad with E.ON Scholarship
10/2009 - 08/2012	**Münster University of Applied Sciences** Bachelor of Science in Industrial Engineering
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WORKING EXPERIENCE

02/2019 - current	**Institute of Energy Economics at the University of Cologne** Manager & Head of Gas Markets
01/2015 - 01/2019	**Institute of Energy Economics at the University of Cologne** Research Associate
06/2018 - 07/2018	**International Energy Agency (IEA)** Consultant; Gas, Coal & Power Division; Energy Markets & Security Directorate
07/2017 - 11/2017	**International Energy Agency (IEA)** Consultant; Gas, Coal & Power Division; Energy Markets & Security Directorate
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LANGUAGES

German	Mother tongue
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PUBLICATIONS AND PRESENTATIONS

Articles in Refereed Journals:

- S. Schulte, F. Weiser (2019). Natural Gas Transits and Market Power – The Case of Turkey. *The Energy Journal*, Vol. 40 (2). DOI 10.5547/01956574.40.2.ssch.
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Working Papers:

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- I. Berk, S. Schulte (2017). Turkey's Role in Natural Gas – Becoming a Transit Country?. *EWI Working Paper* 17/01.

Further Publications:

- M. Schönfisch, S. Schulte, C. Fernandez Alvarez, (2018). IEA Market Report Series: Coal 2018. *IEA/OECD*.
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- Options for gas supply diversification for the EU and Germany in the next two decades. *40th Bruegel Event: Different perspectives on Nord Stream II*. Februar 2017. Brussels, Belgium.
- The prospects of Ukraine as a gas transit country. *40th 2nd Ukrainian Gas Forum*. October 2016. Kiev, Ukraine.
- LNG import quotas in oligopolistic markets - What are the benefits for the European Union's natural gas market?. *39th 1st IAEE Eurasian Conference*. August 2016. Baku, Azerbaijan.
- Options for diversifying the European Union's natural gas market. *39th ENERDAY 2016 - 11th Conference on Energy Economics and Technology*. April 2016. Dresden, Germany.
- Turkey's Role in European Natural gas Supply Security. *39th PhD Seminar: Turkey in the Global Energy Scene - Economic and Political Dimensions of Turkey's Rising Importance*. October 2016. Istanbul, Turkey.
- Turkey's Potential as a Future Energy Hub - Economic Developments and Political Options. *39th Blickwechsel Conference of Mercator Foundation*. October 2016. Istanbul, Turkey.
- Development of a European natural gas market model for the security of supply analysis - Potential impacts of the Russia-Ukraine conflict on the European Union's security of supply. *39th Bergen Economics of Energy & Environment Research Conference (BEEER)*. May 2016. Bergen, Norway.