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Love it or hate it …
Is it possible to find equilibrium in natural gas trade?
Study on the Polish-Russian natural gas trade.

(Draft version – not for citation)

JEL codes: F13, Q48

Abstract
International trade in natural gas has become recently fiercely discussed topic, for a number of reasons. Just to mention the most important. Firstly, energy resources are unevenly distributed across the globe and majority of countries has to import them. In result, states are dependent on single suppliers. Secondly, due to changes in world politics and trade, not only new energy superpowers emerged but also new energy resources caught the attention of markets. One of such commodities is natural gas, which gained popularity thanks to its lower than compared to other fossil fuels (e.g.: hard coal, lignite, crude oil), GHG emissions. Rising concerns over the gas supply security, make researchers and decision makers look for empirical measures suitable to estimate equilibrium point in the natural gas trade. There is great variety of econometric models evaluating multilateral equilibrium in natural gas trade. However, none of them, explicitly indicates equilibrium in bilateral gas trade.

My research consists of hypotheses tests of existence of equilibrium in bilateral gas trade. The goal of the paper is to check if the equilibrium in bilateral gas trade exists in Polish-Russian gas trade. I have chosen the analyzed case on the basis of its relevance to topic. Theoretical underpinnings refer to trade (inter-) dependency concept, whereas empirical focus on trade concentration and dispersion measures.

The concept of security of energy supplies has grown in the times oil crises of the seventies when OPEC reduced oil production. With the passage of time, change of the geopolitical structure of the world, the emergence of stringent climate protection standards, the primary focus shifted to the environment-friendly fuel - natural gas. Demand for natural gas, contributed to increase in importance of Russia, which was weakened at that time by economic transition. Although the concept of security of energy supplies was originally associated only with crude oil, then as the time went by it had become an integral part of the natural gas market. This phenomenon is analyzed not only theoretically but also empirically.
The goal of the research is to check the influence of the LNG terminal construction on the Polish security of supply. In order to do that, empirical research on the sample of Polish gas import including years 2010-2020 will be conducted. Paper consists of three parts. In the first there is a brief description of what security of energy supply really is. The second part shows method that was employed in the empirical research, while the last, third, depicts research results and conclusions.

In the preparation of this article both literature studies, using the method of critical analysis of literature, as well as empirical studies, using the research tools used in international economics, were applied.

The concept of security of energy supplies

Security of supply is an interdisciplinary concept. Explanation of what security of supply is, might be found in political science, engineering science and economics. Security of supply can refer both to the domestic market (the internal dimension of security of supply) and the foreign market (the external dimension of security of supply). The internal dimension of security of supply refers to the challenges related to the processes of market liberalization in electricity and natural gas, while the external - imports. Security of supply includes both the final energy and primary. Therefore, this concept includes both the import of energy resources and electricity.

The concept of security of energy supplies appeared for the first time in the seventies of the twentieth century as a result of oil crises. Since that time, it was the subject of research, mainly in relation to the oil market. M. Adelman2 wrote then that the concept of security of energy supplies is associated with insurance in case of oil supplies disruption. Over the last forty years, the structure of geopolitical world changed significantly. Technological progress

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2 Wrote on oil disruption supplies in 1969-1970: “What is real security problem? There have been two sudden reductions of supply ten years apart, and there can be more at any time on short notice. (...) we want assurance against being struck without a warning”, “Hence the extreme of security problem is clear enough: be prepared for a total cessation for a limited period of time”. M. Adelman, Security of Eastern Hemisphere Fuel Supply, M. Adelman, The Economics of Petroleum Supply, MIT, Massachusetts 1993, pp. 469-472.
has enabled the development of energy resources before being economically inefficient. In addition, in the nineties - importance of a new fuel - natural gas, increased. For these reasons, today the security of energy supplies is not associated only with the oil market but it also applies to natural gas market.\(^3\) Interdisciplinarity of a term security of energy supplies means that it is defined in different ways. Common elements of all definitions are: the physical continuity of energy supplies and the price at which the materials are supplied.\(^4\) This gives the full definition of security of supply, presented by B. Barton, C. Zillman and D. Redgewell.\(^5\) Due to fact that natural gas is imported to Poland primarily on contracts with gas price indexed to crude oil prices and a price formulas are subjected to commercial confidentiality, it is impossible to take into account the exact price of natural gas in the study. That is why, the main element taken into consideration in further research will be the physical aspect - the continuity of gas supply. Security of supply is evaluated within the risks that may be associated with it. Among the threats to security of supply related to the import G. Luciani\(^6\) includes supply side risks connected with suppliers, such as disruption in the supply continuity. That approach will be taken into consideration.

**Empirical research**

The literature describes a number of measures used for assessing the security of energy supplies. There is no consensus, which is the right tool to study the phenomenon. According to Ch. Coq and E. Paltseva\(^7\) these tools can be divided into two groups. The first includes those indicators in which the factors used to assess the security of energy supplies from abroad are

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5. “A condition in which nation and all, or most, of its citizens and businesses have access to sufficient energy resources at reasonable prices for foreseeable future free from serious risk of major disruption of services”. B. Barton, C. Redgewell, D. Zillman, *Managing Risk in a Dynamic Legal and Regulatory Environment*, Oxford University Press, Oxford 2004, s. 5.


merely a component of more complex measures of security of energy supply (total), while the second includes measures that focus only on the assessment of security of energy supplies from abroad, which are of special interest in this paper.

The group of indicators for evaluating the security of energy supplies from abroad includes indicators proposed by W. Blyth and N. Lefevre, Ch. Coq and E. Paltseva and S.

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9 Described measures of security of foreign energy supply do not include the impact of changes in the HHI index value due to changes in relative and absolute concentration. W. Blyth and N. Lefevre, in December 2004. W. Blyth and N. Lefevre stress, that argument convincing them to use the HHI index was the fact that it places greater emphasis on large suppliers, whose role in shaping the security of supply of energy from abroad is higher. The first index takes into account only the part of suppliers in the import of energy. This percentage is referred to as so-called: net export potential (called net exports potential) and the difference of raw material production in the exporting country's domestic net of consumption. Measure adopts the form and scope of the basic version of the HHI index. Analytical interpretation is as follows: the smaller (larger) value of the index, the lower (higher) concentration of suppliers in the market. Interpretation of changes in concentration in this market is opposite to the interpretation of security of supply. The higher the index value, the higher the concentration, and the less safe, and vice versa. In the next step, the authors take into account the political stability of suppliers, which is determined based on indices provided by PRS Group. The measure takes the following form:

\[ G_{MC_f} = \sum_i \eta_i \cdot (u_{if})^2 \quad \eta_i \in (0\%-100\%) \]

where:
- \( G_{MC_f} \) means the security of gas supplies from abroad;
- \( r_i \) is the political stability of the exporter;
- \( u_{if} \) is part of the exporter in the supply of a particular market.

Index takes a value of from zero to three, due to the political stability index values. Index is equal to zero at the lowest concentration of suppliers with a high political stability (100%) and is the highest level of security of supply. The index is equal to three with the largest concentration of suppliers of intermediate level of stability (30%) and is the lowest level of security of supply. In the next step, the authors take into account the flexibility of the raw materials market in the importing country. Researchers assume that the greater the flexibility of the market, the greater the benefits can reach its participants, which manifest themselves in a casual change of suppliers. The measure takes the form:

\[ G_{MC_f} = \left[ \sum_i \eta_i \cdot (u_{if})^2 \right]^{1/2} \quad P_f \geq 100 \]

\( P_f \) is market flexibility is the parameter.
Gupta. These measures are based on the Herfindahl Hirschman index (HHI). Herfindahl Hirschman index is known in economics as the Herfindahl index. It was used for the first time in the U.S. to study competition in the steel industry. It is commonly used in economics as a measure of market concentration. It also found application in the antitrust law for the assessment of mergers and acquisitions.

Using the Herfindahl Hirschman Index in the assessment of security of supply is mainly bound with the assessment of the degree of fuel supplies’ concentration. Ch. Coq and

\[
GMC_f = \left( \sum_i \eta_i \cdot (\psi_i)^2 \cdot \phi_i \right) \cdot \frac{C_f}{TPES}
\]

where:
\(C_f\) denotes the total consumption of raw of the country;
\(TPES\) is total primary energy supply (of all types: either natural gas, petroleum, and coal, etc.) in the country.


Herfindahl index, is one of many indicators, to assess the concentration of market players. This group also includes: the Gini index (often used to illustrate the inequality of income distribution in the population) and the Lerner index.
E. Paltsev\(^{15}\) consider Herfindahl Hirschman as better suited to assess the security of supply of energy from abroad, because it focuses on larger suppliers.\(^{16}\) Disruptions in the continuity of imports from such suppliers are much more dangerous for the economy than a disruption in supplies from small exporters. Furthermore, the smaller supply of a particular country makes it possible to change the exporter, in case of imports disruptions, while bigger - not.

Herfindahl Hirschman index takes the form:

\[
HHI = \sum_{i=1}^{n} u_i^2
\]

where:

- \(i\) denotes the number of suppliers,
- \(u\) denotes the share of individual providers in the market.

Decomposition of the HHI index takes into account the differences in changes in concentration caused on the one hand by: distribution of the analyzed traits (uneven distribution of characteristics), on the other hand by the number of countries under consideration. In this way we receive, respectively: relative and absolute concentration. As a result of decomposition of the HHI takes the form:

\[
HHI = \frac{V^2}{n} + \frac{1}{n}
\]

\[
V^2 = n \sum_{i=1}^{n} u_i^2 - 1
\]

The right part of the sum of the above equation is approximately the relative concentrate on (KW), and the second the absolute concentration (KA). Both KA and KW can take values from 0 to 1.\(^{17}\) When KA is equal, respectively, to 0 albo1, and KW is equal, respectively, to 1 or 0, then we are dealing with a single vendor, dominant in the importer’s market. Changes in the value of the component of KA are inversely proportional to the number of suppliers. The larger the value of KA, the smaller number of suppliers in the market the importer. In turn, the smaller the value of KA, the greater the number of suppliers. KW illustrates the unevenness of


\(^{16}\) Greater impact on the HHI values have those suppliers whose participation greatly exceed the arithmetic mean. W. Rogowski, op. cit., pp. 45.

the analyzed traits (supply on the importer’s market). Therefore, the more uneven is imports’
distribution, the higher values reaches KW. Which means that the greater the share of
individual providers or groups of providers in the importer’s market, the higher the KW is.
Conversely, the more even distribution of the analyzed traits (supply to the market the
importer), the lower the value of the KW.

<table>
<thead>
<tr>
<th>HHI value and its interpretation</th>
<th>Significant change</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0,1 lack of concentration</td>
<td>NA</td>
</tr>
<tr>
<td>&lt;0,1; 0,18: moderately high concentration</td>
<td>by 0,1</td>
</tr>
<tr>
<td>≥0,18 high concentration</td>
<td>by 0,05</td>
</tr>
</tbody>
</table>

Economic interpretation of HHI variation will be based on the methodology used for
interpreting the concentration of the energy market. According to this methodology, the value
of the HHI of less than 0.1 – means that there is no concentration, while between 0.1 and 0.18
– denotes a moderately high concentration and values above 0.18 mean high concentration.
These are not only the index values but also their changes that matter. The decrease ratio of
0.05 at a very high concentration and about 0.1 at moderately high concentration, denote a
significant change in concentration. The decrease in the HHI of 0.1 at very high concentration
also shows a significant decline in the market power of a single supplier. HHI has no
interpretation in natural units. You can only save it in the form of percentage points and thus
interpret the results but still this is not obligatory.

The time horizon includes years 2010-2020. Closing date for analysis (2020) comes
from the fact that in 2020 a decision has to be made whether to increase the capacity of the
LNG terminal or not.

The term "supplier" means the supply of the country / group of countries, which
PGNiG S.A. denotes as a supplier. Deliveries can apply to both single country and group of
countries. Examples are the Central Asian gas supplies, which concluded on 17 November
2006 contract with RosUkrEnergo AG. These included the import of gas from the group of
the Central Asian countries. The statistics of PGNiG S.A. imports from this region are
denoted as the purchase of gas from group of Central Asian countries. Bearing in mind that
the gas reaching the Polish border may be a mixture of gas from different countries and that
there is no real possibility to identify the origin of gas sent to Poland, to simplify calculations,
it is assumed that gas imports from a particular country or group of countries consist of material owned by the exporting country and that exporting country is gas source of origin. Import structure stems from the fact that in 2011 the capacity of interconnector at the Czech border was increased to 0,5 bcm annually and German – to 1,5 bcm. Imports from Russia where calculated on the basis of their year-to-year average import growth. The sum of natural gas imports is still below the forecasted natural gas demand.

<table>
<thead>
<tr>
<th>Table 2. LNG gas imports scenarios (bcm/yearly)</th>
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<tbody>
<tr>
<td>No</td>
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<tr>
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<tr>
<td>1</td>
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</tbody>
</table>

Source: Own calculations

Option 1 assumed an annual import the LNG terminal of 1.5 bcm of gas carried by a single supplier. Case 2 concerned the 5 bcm annual imports delivered by single, four or eight countries. The last, third case, assumed increased LNG imports of 7,5 bcm yearly delivered by, respectively, one, three, five or eight suppliers. All that is done to check how the structure of suppliers influences trade concentration.

<table>
<thead>
<tr>
<th>Table 3. Polish gas imports 2010-2020 (mcm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>---</td>
</tr>
<tr>
<td>Czech Republic</td>
</tr>
<tr>
<td>Russia</td>
</tr>
<tr>
<td>Germany</td>
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<tr>
<td>LNG (1)</td>
</tr>
<tr>
<td>LNG (2)</td>
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<tr>
<td>LNG (3)</td>
</tr>
</tbody>
</table>

Source: Own calculations

Conclusions

Comparison of different scenarios included in the research show that in all of the analyzed cases trade concentration decreases considerably in 2014 compared to 2010. However, according to standards employed to evaluate level of concentration – with HHI
values above 0.18, that still remains high. Knowing that HHI dropped in the analyzed time period, analysis of HHI changes, brings us additional conclusions. All of the drops were greater than 0.1, which denotes significant changes. That is why, even though HHI values remain still high, they had changed significantly as compared to 2010 levels.

Between analyzed scenarios there are several differences. What is obvious the greater quantities of LNG were imported, the greater was concentration decrease (1.5 bcm – HHI_{2014}=0.6; 5 bcm HHI_{2014}<0.46; 0.43>; 7.5 bcm HHI_{2014}<0.43; 0.28>). That is an effect of dominant position of a single supplier on the Polish gas market that, in fact, will be balanced by additional LNG supplies. However, the increase of LNG imports from 5 bcm to 7.5 bcm was accompanied by the HHI decrease only of 0.03, what would suggest that concentration drops are not proportional to the increase in import quantities.

**Table 4. Absolute and relative concentration values in different scenarios**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Relative concentration value (KW)</th>
<th>Share in HHI</th>
<th>Absolute concentration value (KA)</th>
<th>Share in HHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 bcm of LNG yearly: 1 supplier: A</td>
<td>0.39</td>
<td>66%</td>
<td>0.2</td>
<td>34%</td>
</tr>
<tr>
<td>5 bcm of LNG yearly: 1 supplier: A</td>
<td>0.25</td>
<td>55%</td>
<td>0.2</td>
<td>45%</td>
</tr>
<tr>
<td>5 bcm of LNG yearly: A,B:1,5 bcm each, C,D:1 bcm each</td>
<td>0.27</td>
<td>73%</td>
<td>0.2</td>
<td>28%</td>
</tr>
<tr>
<td>5 bcm of LNG yearly: A:1,5 bcm; B, C, D, E, F, G, H: 0.5 bcm</td>
<td>0.3</td>
<td>79%</td>
<td>0.08</td>
<td>21%</td>
</tr>
<tr>
<td>7.5 bcm of LNG yearly: 1 supplier: A</td>
<td>0.22</td>
<td>50%</td>
<td>0.2</td>
<td>50%</td>
</tr>
<tr>
<td>7.5 bcm of LNG yearly: A: 5 bcm, B:1,5 bcm each; C: 1 bcm each</td>
<td>0.21</td>
<td>68%</td>
<td>0.14</td>
<td>32%</td>
</tr>
<tr>
<td>7.5 bcm of LNG yearly: A, B, C, D, E: 1.5 bcm each</td>
<td>0.18</td>
<td>94%</td>
<td>0.1</td>
<td>6%</td>
</tr>
<tr>
<td>7.5 bcm of LNG yearly: A, B, C, D, E, F, G: 1 bcm each; H: 0.5</td>
<td>0.22</td>
<td>73%</td>
<td>0.08</td>
<td>27%</td>
</tr>
</tbody>
</table>

Source: Own calculations

Another important observation is the balance between the increased number of LNG suppliers and values of HHI. Research showed that expanding the number of suppliers in 5 bcm LNG import from four to eight and in 7.5 bcm from five to eight, in fact, increases concentration (HHI_{5,bcm,ABCD} = 0.39; HHI_{5,bcm, ABCDEFGH}=0.40; HHI_{7.5,bcm, ABCDE}=0.28; HHI_{7.5,bcm, ABCDEFGH}=0.31). If we were to add to that transaction costs needed to sign additional contracts, we might further worsen the achieved outcome. In all the cases it was the relative concentration (KW), that shaped the value of HHI. Very clearly it was visible in scenario of 7.5 bcm of LNG import with five suppliers, when KW influenced HHI in 94%. Absolute concentration had similar to relative concentration impact only in the
case of 7.5 bcm import from 1 supplier (KW=0.22; KA=0.22). It suggests that it is the uneven distribution of import quantities not number of suppliers that really affect HHI values.

Summing up, the research shows that while trying to increase the security of gas supply, careful analysis including not only the number of suppliers but also the import quantities is needed. It is important not to cross the equilibrium point where gains from increased number of suppliers or import distribution will not decrease the supply security. As that equilibrium point is country specific, careful analysis for individual cases is needed. The “love or hate” thing refers to both the measure used in research and the single supplier the importer is buying gas from. Firstly, HHI is not a perfect measure, but such ones simply do not exist. It has its drawbacks for which you may hate it, such as: greater emphasis on bigger suppliers or problematical ways of the results interpretation. However, if they are discounted by reasonable explanation which deliver, respectively Ch. Coq, E. Paltseva 18 and US FERC19, you may love it for its simplicity. Secondly, you may hate the dominant supplier, but remember as not to exaggerate with the diversification measures, because this is still the quantity of gas imports that really matters, not the number of suppliers.

References:


Chart 1. Comparison of different scenarios denoted by HHI values

Source: Own calculations