POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2020 ✦ Volume 23 ✦ Issue 1 ✦ 19–36

DOI: 10.33223/epj/116334

Honorata Nyga-Łukaszewska[1]

Energy security externalities – phenomenon description

Abstract: Energy security is one of the most frequently analysed phenomena in the energy markets. Great variety of scientifc efforts should have indicated clear definition of the phenomenon. However, those studies highlighted more than 80 different definitions of what energy security really is. Due to the fact, that energy security is analyzed by different scientific disciplines, studies have provided a comperehensive reflection on the phenomenon.

The main objective of this paper is of the theoretical nature and focuses on showing energy security externalities. Author delivers an integrative review focusing on existing literature referring to the analyzed phenomena. Energy security is though studied only from the perspective of economics therefore interdisciplinary studies are out of the study scope. The reason for such scientific procedure stem from a belief that each discipline approach is different in terms of concepts, research methods and though results that are obtained. Therefore without undermining high value of interdisciplinary approaches to energy security, author decided to concentrate solely on economic perspective, which in energy security studies seems to be underestimated. Such approach in author's belief helps achieve theoretical clarity of the below given analysis.

Presented paper is of the theoretical nature and focuses on showing energy security externalities. Critical literature review shows the literature mainstream in which energy security externalities are

✉ Corresponding Author: Honorata Nyga-Łukaszewska; e-mail: honorata.nyga-lukaszewska@sgh.waw.pl

[1] SGH Warsaw School of Economics, Poland; ORCID iD: 0000-0003-1615-9991; e-mail: honorata.nyga-lukaszewska@sgh.waw.pl

© 2020. The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution-ShareAlike International License (CC BY-SA 4.0, http://creativecommons.org/licenses/by-sa/4.0/), which permits use, distribution, and reproduction in any medium, provided that the Article is properly cited.

depicted from the point of energy imports and disruption costs, in particular. Majority of identified externalities is of pecuniary nature, which means that they are not a symptom of market inefficiency. Paper presents also selected measures that aim at externality capturing.

Keywords: energy security, externality, natural gas

Introduction

Energy security is one of the most frequently analyzed phenomena in the energy markets. Between 2001 and 2014 there were released 104 research papers dealing with the energy security (Ang et al. 2015). Such a great variety of scientific efforts should have indicated clear definition of the phenomenon. However, those studies highlighted more than 80 different definitions of what energy security really is (Ang et al. 2015). Due to the fact, that energy security is analyzed by different scientific disciplines, studies have provided a comprehensive reflection on the phenomenon.

The main objective of this paper is of the theoretical nature and focuses on showing energy security externalities. The authors deliver an integrative review focusing on existing literature referring to the analyzed phenomena. Energy security is, however, studied only from the perspective of economics therefore interdisciplinary studies are outside the scope of this study. The reason for such a scientific procedure stems from a belief that each discipline approach is different in terms of concepts, research methods and through the results that are obtained. Therefore without undermining the high value of interdisciplinary approaches to energy security, the authors decided to concentrate solely on the economic perspective, which studies seems to be underestimated in energy security. In the authors' belief, such an approach helps achieve theoretical clarity of the analysis given below.

The text is organized in three parts. The analysis is introduced by a description of the motivation and study goal. Afterwards, text highlights externalities and energy security as phenomena of research are presented. The third part referring to energy security externalities in economics is followed by a conclusion.

1. Externalities in economics

The externality discussion in economics stems from a belief that markets do not always allocate resources efficiently. That is why externalities in economics are a form of market failure. The externalities debate is an inherent part of public sector economics and welfare economics.

This stream in economic literature focuses on the role of the state in the economy, public choice theory, public goods and Pareto optimum, market efficiency and failures.

According to Mankiw and Taylor (2006) an externality is an uncompensated impact of one person's action and the well-being of a bystander. If this impact is adverse – negative externality is observed, if it is beneficial – positive. Another way of explaining externalities is provided by Silvestre (2012). He claims that externality arises when "the utility function of a consumer *i*/ production function of a firm *j* (…) includes consumption/production variables whose values are chosen by other consumers or firms without particular attention to the welfare of consumer *i* (or the profits of a firm *j*)". In this sense consumer *i* or a firm *j* becomes the recipient of the externality and other companies or persons choosing variables entering consumer *i* utility or a firm *j* production function are called generators of the externality. Silvestre's definition of an externality is clear in the division of the two externality types. These are production and consumption externalities. The former refer to the activity of persons and the latter – companies. In the case of companies, Silvestre (2012) additionally distinguishes between an "external economy" (or "external economy of scale") and an "external diseconomy" (or "external diseconomy of scale"). External economies refer to the positive impact of production externalities and external diseconomies – of the negative. The above mentioned externalities have mainly referred to consumer-consumer or producer-producer relations. However, as Howard (2001) highlights, there is another type of an externality, which pertains to the impact of consumer on a company's behavior. He calls it consumer-producer externalities admitting that they are rare in economic practice.

Silvestre (2012) breaks externalities into unidirectional and omnidirectional. The former describes a situation in which consumption of one person *i*/ production of a company *j* generates externality on the other, while the other's consumption/production does not affect person *i*/company *j*. However, externality can run in both directions and in such a case it is called an omnidirectional one. In this situation one person *i*/ production of company *j* generates externality on the other and at the same time the other's consumption/production affects person *i*/company *j*. In the unidirectional dimension, externality generators and recipients constitute different groups and in omnidirectional – externality generators and recipients may form the same group.

In negative externality (Fig. 1) the social cost is larger than the private cost. The social cost includes the cost of a negative externality and private cost. At the same time the equilibrium quantity (Q *market*) is greater than the optimum quantity (Q *optimum*). As a result, negative externalities bring overproduction. This inefficiency results from the fact that equilibrium includes only the private cost. Negative externalities are broadly discussed in the economic literature. An exemplary catalogue of negative externalities includes: environmental externalities such as: pollution, greenhouse gases emissions (GHG), congestion or the commons such as exploitation and depleting natural resources such.

In positive externality, (Fig. 2) social value is larger than the private cost. Social value includes the benefit of externality and private value. At the same time the optimum quantity (Q *optimum*) is greater than equilibrium quantity (Q *market*). AN exemplary catalogue of positive externalities includes (Silvestre 2012): vaccination or education. Others include: network or agglomeration externalities. Network externalities arise when joining the network increases the

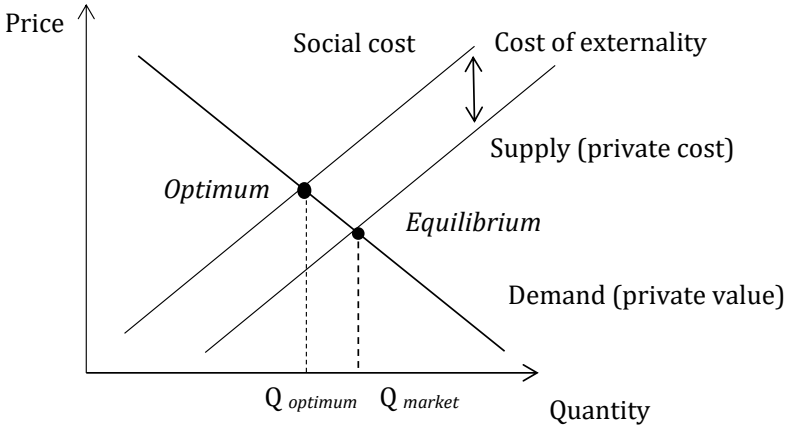

Fig. 1. Negative externality
Source: own work based on Mankiw and Taylor 2006

Rys. 1. Negatywny efekt zewnętrzny

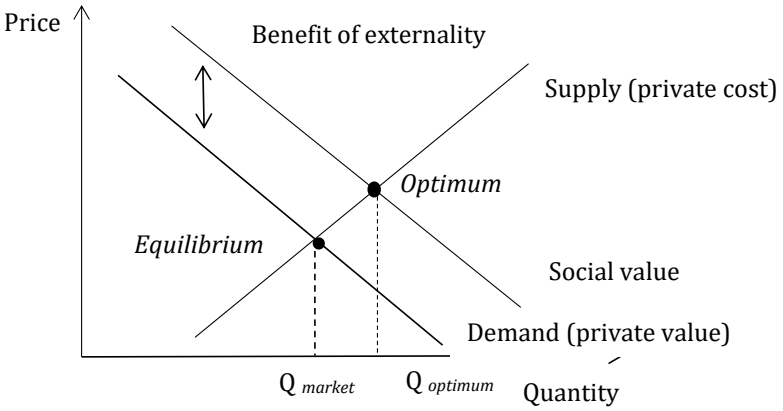

Fig. 2. Positive externality
Source: own work based on Mankiw and Taylor 2006

Rys. 2. Pozytywny efekt zewnętrzny

value to all its users. This usually refers to telecommunication or IT industries. But it can also result from the adoption of a common standard or language. In this sense network externality is positive and omnidirectional. Agglomeration externalities occur when the cost of interaction between different economic actors decreases as they locate closer to each other. The last positive externality Silvestre (2012) depicts is an endogenous growth resulting from innovation and knowledge spill-overs, which are the consequence of international investment in R&D or learning-by-doing processes.

A positive externality in the consumption example is vaccination. The fact that one has been vaccinated against infectious diseases benefits the society. Due to vaccination, disease does not spread across the neighborhood or region. Smoking, for instance constitutes a negative externality in the consumption example. When someone smokes a cigarette the rest is forced to breathe in the smoke and thus that makes them vulnerable to various diseases.

Externalities can be distinguished with the reference to the externality subject and geographical scope (Garbicz and Staniek 2010). The former includes not only product or services externalities but also production factor externalities. The latter pertains to external effects on a national or global level (e.g.: greenhouse effect).

There are pecuniary externalities as well. In the case of pecuniary externalities there is a change in prices of respective products/services without any market inefficiency. On the contrary, Papandreu (1998) rightly sees a pecuniary externality as a signal of market efficiency. He believes that any price adjustment is an indication of a well-functioning price system (Interesting discussion about pecuniary externalities deliver: Greenwald and Stiglitz 1986).

Another problem connected with externalities is the commons problem. This idea was introduced in contemporary economic thought in 1968 by Garrett Hardin, who relied in his line of reasoning on the paper by Lloyd from 1833. Lloyd originally depicted a situation of common land used for grazing purposes. He believed that common pastures are over-used as a consequence of the fact that they were common resources. This idea was brought by Hardin, who in published the text in "Science" journal, made it popular. The commons problem or the commons tragedy is depicted when individual users over-exploit the common resource leading to its depletion. Such an action definitely acts against a common goal which should be resource protection. Hardin gave example of national parks as one of the common resources. He highlighted that as parks are open to everyone without any limits, their natural value is steadily eroding. Other examples of the tragedy of common resources include: overfishing, deforestation, pollution and climate change and the depletion of oil and gas reservoirs.

Internalizing external effects can take two forms: public and private (Stiglitz and Rosengard 2015). Private includes: lawsuits, property rights definition or establishing greater economic units such as corporations or partnerships. Lawsuits are a solution aimed at compensating a negative externality recipient. Clarifying on property rights is a solution brought by the Coase theorem accordingly to which private parties can fight the externalities problem once they can bargain over it without any additional costs (Mankiw and Taylor 2006). Building larger economic units, like big home residential areas, help control externalities. In this case that might be the need for an esthetic balconies look (Garbicz and Staniek 2010).

Sometimes, however, private solutions do not work due to transaction costs. This happens when the cost of reaching an agreement for an externality generator and recipient is too high. Therefore in such cases, public support is needed. The selection of public methods used to overcome externalities includes: taxes and subsidies, regulation and trade allowances. Using market-based mechanisms can either discourage from negative externalities or encourage positive externalities. In the first scenario, the government uses taxes while in the second it uses subsidies. The fiscal burden is levied in the form of the so called Pigouvian tax which aims at balan-

cing social and private marginal costs. Unlike other taxes, the Pigou tax allocates the resources closer to the social optimum (Mankiw and Taylor 2006). Administrative regulations, like taxes and subsidies, either incentivize or disincentivize certain types of behavior.

Regulations are usually used when correcting environmental externalities and take two forms: performance based regulations and input regulations. The former solution focuses on results without showing the means of achieving them. Yet the latter pays greater attention to particular solutions used in meeting required standards. None of the two regulation types is perfect. On the one hand, input regulations are the better option when there is a need for clear and easy strategy implementation monitoring. But on the other hand, input regulations can be a troublesome burden since they are vulnerable to any industry pressure. Such circumstances may particularly occur when firms have different marginal costs of emissions reductions. Internalizing externalities with the use of administrative regulations brings innovations. This effect is intensified in case of performance based regulations (Stiglitz and Rosengard 2015).

2. Energy security externalities

Energy security is a concept which lacks a commonly shared definition. Since the discussion on the phenomenon's understanding requires a separate study for the purposes of this article, the authors will refer only to one of them, which is widely recognized and seems to capture the concept thoroughly. Such an idea was brought by the International Energy Agency (IEA). The IEA defines energy security as "the uninterrupted availability of energy sources at an affordable price". Such an understanding also depicts different time perspectives on energy security: long-term and short-term. Both of them focus on balancing supply and demand, but the former is connected with prospective investments, while the latter refers to sudden disruption events (IEA 2020).

Energy security externalities literature originates in the analysis of oil disruption costs. The majority of works in this literature stream appeared after the oil crises of the seventies of the twentieth century. At that time scientists started to estimate what effects a sudden oil supply shock would have on the international markets. Such research efforts, accordingly to Hedenus, Azar and Johansson (2010), were aimed at finding an "optimal level of taxation on oil imports in order to compensate for externalities associated with an insecure supply". The variety of optimal solutions included additional taxes or policy intervention mechanisms (or their lack). Hedenus refers to oil import taxes between USD 5–15/bbl and stockpiling policies.

Energy security externalities are often depicted as external costs of oil imports. The social cost is larger than the private cost. The social cost includes the cost of a negative externality and private cost. At the same time the import quantity based on private cost (Q_2) is greater than the optimum (efficient) import quantity would be (Q_1). Bhattacharyya (2011) concludes that the

social cost additionally includes the costs of: imperfect competition, environment pollution and price volatility in the energy markets.

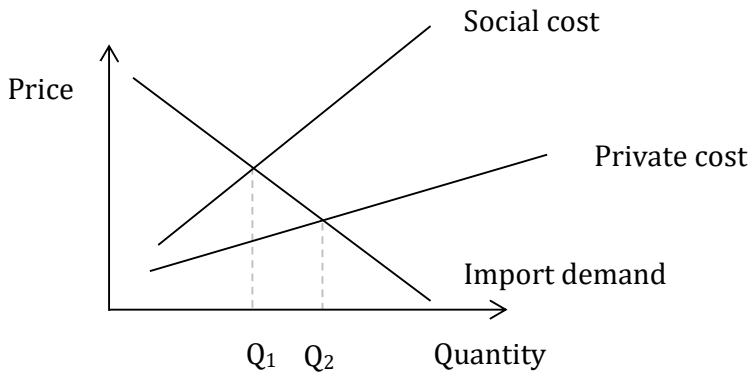

Fig. 3. Social cost of energy imports
Source: own work based on: Bhattacharyya 2011

Rys. 3. Społeczne koszty importu energii

One of the most famous approaches to energy security externalities was brought by Bohi and Toman (1996)*. Other researchers such as: Parry and Darmstader (2003), Markandya and Hunt (2004), Greene and Leiby (2006) and Bhattacharyya (2011) have followed the proposed logic. According to Bohi and Toman (1996), externalities can be divided into three groups. The first includes externalities connected with imports quantity, the second with price of imported fuels while the third refers to military expenditures used to maintain the military presence in areas where fuels are produced.

From the economic point of view, the two first groups constitute the most interesting energy security externalities . Bohi and Toman (1996) divide imports' quantity externalities into direct and indirect ones. The former pertains to the market power exporters or importers exert over their trading partners, while the latter refers to macroeconomic effects of energy imports to the importer's economy.

Thea authors argue that exporters can exert market power establishing an oligopoly as in the oil market. Historically, the Organization of Petroleum Exporting Countries (hereinafter: OPEC) and it's activity during the oil crises of the seventies in the twentieth century may deliver such an example. Bohi and Toman argue that OPEC did not exert market power over importers at that time as the organization increased oil production instead of decreasing it. Essentially, production curtailment would have been a form of exercising market power over oil importers. This result contradicts studies carried out by Golombek, Irarrazabal and Ma (2014). They, indeed, investiga-

* The authors refer to energy security externalities in the form of oil import externalities treating them as the same phenomenon. That is why the authors of this paper follow the same nomenclature logic.

ted different time periods of the OPEC performance (1986–2009) but arrived with a quantitative conclusion suggesting that the organization enjoyed high power in the oil market. It seems worth noticing that the oil market is not the only energy commodity market which may be a research example of exporters' market power. A similar organization operates in the natural gas market. The Gas Exporting Countries Forum (hereinafter: GECF) is an association of natural gas exporters whose declared mission centers around their close cooperation in the natural gas market. Since the organization's establishment in 2001, scientists have made research efforts aimed at checking the GECF* impact over the world's gas market. The most interesting papers investigating this issue are the works of: Gabriel, Rosendahl, Egging, Avetisyan and Siddiqui (2012) and Egging, Holz, von Hirschhausen and Gabriel (2009). By using the World Gas Model, in both cases, the authors check what would be the GECF's influence in the natural gas market with respect to regional prices, consumption, and production in 2030. Both of the studies forecast negative effects for the European markets. According to Gabriel et al. (2012), once a cartel is joined by Caspian and Middle Eastern producers, consumer surplus in Europe decreases by USD 91.4b and gas consumption drops by 21% in 2030. Those negative effects are not visible in the North American gas market, which is said to be isolated. On the contrary, in Egging et al. (2009) intensified cooperation between GECF members not only negatively influences Europe but also North America. In 2030 due to the GECF activity experience in those regions, gas prices will increase by 15–20% and a yearly consumer loss of USD 180b will be noted. Interestingly, half of the extra profits (USD 150b, yearly) earned by upstream gas producers flows to the non-GECF members, who being outside the cartel profit from the cartels' activity. Additionally, Egging et al. (2009) underlines that due to low reserve-to-production ratios, non-GECF members would probably not be able to sustain the higher production levels in the long term. This conclusion only confirms international economics' findings on worldwide cartels' stability. Those determinants include, among others, low price elasticity of the supply of non-cartel producers (Budnikowski 2006). A more detailed analysis of GECF stability and its influence over the gas market can also be found in Nyga-Łukaszewska (2009, 2019), who skeptically assesses the GECF's role as a successful cartel.

Apart from exporters' market power, direct energy security externalities also include importers' market power. Bohi and Toman (1996) convince that the only possible situation in which an importer can exert pressure over the exporter is the monopsony. This is achievable when the importer is a large country – with a substantial share in the world commodity imports – acting as a price-maker not a price-taker (Bhattacharyya 2011). Bohi and Toman (1996) are rather skeptical about a monopsony as a form of externality. They argue that a monopsony wedge, which is a premium for importers earned on exerting market power, is in fact a pecuniary externality as it only redistributes incomes and does not bring ineffective resources allocation.

Indirect externalities connected with oil imports volume include changes in the commodity quantity available in the market, it's prices' surge, increasing import costs and a negative influ-

* GECF members (as of March 2019): Algeria, Bolivia, Egypt, Equatorial Guinea, Iran, Libya, Nigeria, Qatar, Russia, Trinidad and Tobago, UAE, Venezuela. Observer status hold: Angola, Azerbaijan, Iraq, Kazakhstan, Norway, Oman, Peru.

ence over the trade balance, current account balance and consequently the balance of payments. Those effects also influence the importer's currency depreciation. However, Bohi and Toman (1996) find two exceptions to this rule. The first refers to the work of Marion and Svensson (1986) and the second – Krugman (1983). Currency appreciation resulting from an increase of imported fuels was associated, respectively, with improved terms of trade and large USD reserves held by exporters who are willing to counteract any USD depreciation. Indirect oil imports externalities also include inflationary pressure. Again, Bohi and Toman (1996) remain skeptical about the externality nature of exchange rate fluctuations and inflation. They claim, likewise in the monopsony case, that it is only a pecuniary externality which does not affect resources allocation.

Energy security externalities referring to energy prices include effects for energy markets and markets which are not directly connected to energy. Those externalities include: lack of hedging against price volatility, decrease in employment and production. The hedging policy might include: stockpiling, energy-saving consumption or using financial derivatives. Decreasing employment levels result from differences between real wages and energy price increase (under the assumption that in order to produce 1 unit of product both energy and labour are needed as production factors). Rising energy prices reduce energy use and marginal labor productivity. Consequently, wages pressure increases with inflexible labor market conditions would result in production curtailment. However, decreases in production may also result from the premature obsolescence of energy intensive capital, which in times of rising energy prices is not used. Preference only towards energy-saving capital leads to decreased capital use and a drop in production.

Interestingly enough, Bohi and Toman (1996) rightly notice that isolating sole energy security costs of a military presence in areas of oil production from the general costs of the military presence in such areas cannot be done.

The effects of oil import externalities include the redistribution of income between exporters and importers, on the one hand, and the costs of the macroeconomic adjustment mechanisms on the other hand. Hedenus et al. (2010) call it an expected cost of an oil supply disruption which constitutes an economic damage from an oil shock. Such damage can be broken into three categories: wealth transfer, social surplus loss and adjustment costs. Wealth transfer is treated as a pecuniary externality which occurs when oil prices exceed extraction costs. Wealth transfer can be calculated using the following formula:

$$\Delta W = \sum\nolimits_{j \in J} (P^j(p) I^j - P_0^j I_0^j) \tag{1}$$

where:

- j – energy carrier,
- p – price of oil,
- P_0^j – pre-disruption energy price,
- I_0^j – net energy import level,

I^j – post-disruption net energy import level,
P^j – post-disruption price of an energy commodity,
ΔW – wealth transfer.

And post-disruption net energy import level can be estimated by the following formula:

$$I^j = D_0^j \left(\frac{P^j(p)}{P_0^j} \right)^{\varphi^j} - S_0^j \left(\frac{P^j(p)}{P_0^j} \right)^{\nu^j} \tag{2}$$

where:
I^j – post-disruption net energy import level,
D_0^j – pre-disruption energy demand,
φ^j – short term energy demand elasticity,
S_0^j – pre-disruption level of domestic energy production,
ν^j – short term supply elasticity of domestic energy production.

Hedenus et al. (2010) assume that the wealth transfer price of energy commodity is dependent on oil price as in the case of natural gas. That is why the wealth transfer is a difference between the post- and pre-disruption energy commodity price with respective net import levels. The post-disruption net import level is dependent on energy demand and its domestic production including respective short run elasticities for energy carriers.

The macroeconomic adjustment cost is calculated in the following way:

$$M = Y_0 - Y_0 \left(\frac{p}{p_0} \right)^{\mu} \tag{3}$$

where:
M – macroeconomi adjustment cost,
Y_0 – GDP in the absence of energy shocks,
p_0 – pre-disruption energy price,
p – post-disruption energy price,
μ – oil-GDP elasticity.

According to Hedenus et al. (2010), the macroeconomic adjustment cost captures, social surplus loss. Authors additionally claim that macroeconomic adjustment cost is "poorly understood" but at the same time highlight that policies reducing energy consumption decrease this cost. Hedenus et al. (2010) also admit the limitations of such policies. The authors believe that any substitution of oil for another energy commodity having a strong oil price link will not reduce the macroeconomic adjustment cost. By using an example of ethanol, the authors convince that any adjustment cost decrease may result only from ethanol lagged response to oil prices.

The social surplus loss is a deadweight loss for the society which results from the energy price increase. Macroeconomic adjustment costs result from decreased energy capital productivity, sticky wages and the balance of trade effects. These costs depend on the total use of energy in the economy rather than the amount of imported energy.

Another way of looking at energy security externality connected with disruption costs is presented by Leiby (2007), who by updating his 1997 study (Leiby et al. 1997) estimated US disruption cost using the following formula:

$$E_{(\Delta Q)}[C_d] = \sum \varphi_j [C_{Id}(\Delta P(\Delta Q_j)) + C_{GNPd}(\Delta P(\Delta Q_j))] \tag{4}$$

where:

C_d – cost of disruption,
C_{Id} – cost due to import disruption,
C_{GNPd} – cost of economic losses due to economic dislocation,
φ_j – annual probability of supply losses,
ΔP – energy price change,
ΔQ – energy quantity change,
$E_{(\Delta Q)}[Cd]$ – expected cost of disruption.

Leiby's expected disruption cost is the probability-weighted sum of the possible supply losses ΔQ_j each with annual probability φ_j. Each possible disruption ΔQ_j brings an increase in the imported energy price of ΔP and the disruption costs. The latter are composed of the incremental imports costs (foreign payments) plus the dislocational GNP losses due to the disruption price. Incremental import costs during a disruption are given by the change in price times the level of imports. The GDP dislocation component is the marginal change in expected GDP losses during disruptions (Leiby 2007).

Hedenus (2010) and Leiby's (2007) works are based upon the previous works (among other) of Broadman and Hogan (1988), Huntington (2004). Since these are the latest research efforts in this area, the authors decided to focus only on the recent papers.

Interestingly, the literature is not consistent on whether the disruption cost is indeed an externality. In a report titled "Hidden Costs of Energy" published in 2009, the American Research Council focused on possible energy consumption and production externalities. The authors claimed that they constitute energy security externalities. They answer the question whether macroeconomic adjustment cost is an externality which can be quantified. Referring, for instance, to Leiby's (2007) research, they claim that there is no controversy in assessing the link between oil shock and its influence on the economy. However, they question it's externality nature. The authors believe that disruption costs are not an externality associated with energy consumption or production. At the same time they recommend that further scientific investigation is needed to understand this topic deeper. Apart from disruption costs, the American National Research Council (2009) clearly denotes the security of the energy supply as a possible externality. They claim that the security of the energy supply is associated with the risk of energy becoming unava-

ilable. It is even reffered to as the "risk of disruption" highlighting that it may exist when "supply is dominated by one or a few countries (or facilities) that are unreliable or that may choose to restrict supply for political or other objectives" (American National Research Council 2009). The authors argue that "these sources of insecurity are not an externality". They call them "supply conditions incorporated in market outcomes". Here they maintain that any energy buyer, who in that case would be an energy importer in the author's opinion, will implement any possible policies aimed at reducing the risk of disruption, or the magnitude of harm if disruption occurs. A selection of these methods includes: import's diversification, maintaining energy stockpile or having financial insurance. The American National Research Council (2009) additionally distinguishes possible national security externalities. The authors use the example US-Venezuela/Iran oil trade to depict the above mentioned phenomenon. They claim that if oil prices rise and the US continues to buy Venezuelan/Iranian oil, at the same time it supports actions of those countries that may negatively affect the US. The report recognizes oil dependency as a possible externality, however underlines that its monetary assessment is difficult. As in the case of disruption costs, the authors suggest a further scientific investigation to understand this phenomenon better.

Using the logic of American Research Council Metcalf (2013) claims that "there is little if any externality associated with energy production or consumption arising from energy security considerations". Interestingly Metcalf depicts energy security as the "ability of (…) households, businesses, and government to accommodate disruptions of supply in energy markets". Admitting that "the literature on the economics of energy security is thin and has focused in large measure on measuring the externalities associated with energy security", Metcalf believes that this is a "misplaced focus". He maintains that "real energy security issues may be more micro in nature" giving as s an example "costs of bottlenecks in specific locations (e.g. Japan following the Fukushima nuclear power accident or natural gas in supply bottlenecks in New England)" (Metcalf 2013).

Another interesting perspective on energy security externalities bring work carried out under the auspices of the European Investment Bank in 2016 (Paoli et al. 2016). This seems to be one of the latest research efforts on energy security externalities and definitely one of the most clearly depicting the phenomenon. An additional advantage of this research is the fact that it draws upon the existing literature on energy security. In Paoli et al. (2016), the authors aim at providing a tool for energy security assessment in line with its two components: energy physical availability and energy price. This idea employs the energy security perspective manifested, among others, by the International Energy Agency, a global energy security specialized body, which is recognized as the most prominent international organization in the field of energy markets. As authors claim contribution of their study is the quantitative analysis of energy security externalities and presentation of possible means of their internalization. Not surprisingly, Paoli et al. (2016) focus on the natural gas market in Europe as they believe it generates the largest costs of supply security. In this research, external costs are the sum of two components: physical availability and price increase. Physical availability is assessed through the N-1 formula and the so called "standard supply". The former is a method used to estimate whether the gas infrastructure of respective area holds enough technical capacity to satisfy its total gas demand in the event of a disruption

of the single largest gas infrastructure during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years. Compliance with the standard is met for a result equal or greater than 100%.

$$N-1(\%) = \frac{EP_m + P_m + S_m + LNG_m - I_m}{D_{\max} - D_{eff}} \cdot 100, \quad N-1 \geq 100\% \tag{5}$$

where:

EP_m – is the total daily capacity to deliver imported gas at the border entry points,

P_m – is the total daily production capability that can be delivered at the internal entry points,

S_m – is the total daily withdrawal capacity from internal gas storage,

LNG_m – is the total LNG daily capacity to send-out gas at the internal entry points,

I_m – is the daily capacity to supply gas from the single largest gas infrastructure. When several gas infrastructures are connected to a common upstream or downstream gas infrastructure and cannot be separately operated, they shall be considered as one single gas infrastructure,

$D_{\max}$ – is the daily maximum demand occurring during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years,

D_{eff} – is the daily demand that can be covered with market-based demand-side measures.

The N-1 formula can be calculated both at national and regional level. For the calculation of the N – 1 formula at regional level, the single largest gas infrastructure of common interest shall be used. The authors claim that "the willingness to pay to avoid gas supply disruption can be calculated from the costs to meet this standard" (Paoli et al. 2016).

The supply standard in the physical availability component pertains to supply disruption occurring when the existing capacity is fully available but is still not sufficient to meet the demand. This cost can be calculated on the basis of the use of tools such as physical storage or other contractual arrangements.

The price component in energy security externality comprises of the welfare loss and the willingness to pay of a risk averse society in order to limit the potential damage. Welfare loss is a concept, calculated identically as the World Bank's (2005) simple net import model.

$$\%\frac{\Delta GDP}{GDP} = \%\frac{\Delta P}{P}(1-\varepsilon)\frac{NI}{GDP} \tag{6}$$

where:

$\%\frac{\Delta GDP}{GDP}$ – is the percentage change in GDP,

$\%\frac{\Delta P}{P}$ – is the percentage change in price of imported energy,

ε – is the price elasticity of demand (in absolute value),
NI – is the net import of energy (in monetary terms).

Welfare loss depends on the magnitude of the price change and characteristics of the respective economy. It can be described through GDP, the share of imported energy costs in GDP and the flexibility of the demand. As Paoli et al. (2016) "the external cost associated with energy price increases depends on its expected value. This value is obtained by multiplying the monetary consequences of the accident by the probability of occurrence of the accident". Expected welfare loss is the weighted average of all possible welfare losses.

The willingness to pay of a risk averse society is introduced in the formulas as a second order component added to the welfare loss. It is been assumed that the perceived social welfare losses rise as net import increases.

$$\%\frac{\Delta GDP}{GDP} = \%\frac{\Delta P}{P}(1-\varepsilon)\left[\frac{NI}{GDP} + \alpha\left(\frac{NI}{GDP}\right)^2\right] \tag{7}$$

where:

α – is the risk aversion coefficient: the higher α, the higher economic losses.

A similar approach to energy security externalities was depicted in the Externe-pol project from 2005 (Externe-pol 2005), where external costs were associated with price spikes and physical interruption of supplies. These externalities are said to be both pecuniary, as they affect the welfare of another respectively by price changes and through other means than prices. Assessing the welfare losses relies on the implication for GDP due to price changes and their volatility and calculating the willingness to pay to avoid supply disruption. The latter in the electricity market is called VOLL – Value of Lost Load and can be estimated with the use of econometric modelling, case studies of supplies' disruptions or the most prominent method used in this area – customer surveys.

An interesting approach to energy security externalities is also offered by another work, which derives mainly from the Bohi and Toman working paper from 1993, which then became the basis for their book published in 1996. The paper seeks to identify energy security externalities connected with a different choice of fuel. Using the energy securities externality approach of Bohi and Toman, the authors examine potential externalities connected with the volume and price of oil imports, variability of oil prices and additionally, private incentives for R&D which cause fuel cycle comparisons. Study results show that fuel cycle decisions on the national level may have an effect on price. Nevertheless, the authors believe that such reasoning cannot be treated as a strong evidence towards policy coordinating fuel cycle decisions of individual customers. Probably the most interesting part of this research is it's R&D component, which makes it an innovative approach towards energy security externalities. While examining the intersects between energy security externalities and R&D externalities, the authors find out that they have an effect over market power of energy exporters and adjustment costs. The authors convince

that R&D in cost-effective, alternative energy sources and energy-saving technologies can significantly reduce market power of exporters in the long-term perspective. They also claim that any improvement in energy conservation and flexible energy storage mitigates adjustment costs resulting from energy price shocks.

Concluding remarks

This paper examines energy security externalities. Critical literature review shows the literature mainstream in which energy security externalities are depicted from the point of energy imports. Without any doubt the reason for such a methodological approach stems from the history of energy markets dominated by oil crises in the 1970s and 1980s. Due to this fact, energy security externalities were mainly examined from the disruption costs' perspective.

It's important to note that according to the literature, energy security externalities are pecuniary in their nature, which means that they are not a symptom of market inefficiency. At the same time closer look at energy security externalities brings reflections on their economic nature. Firstly, in case of imports, the disruptions externality generator is an exporting country and the recipient – an importing country. Secondly, it seems at last at first glance that they are unidirectional as imports disruption effects only the externality recipient. This seems to be true in the short-term. However, this logic is not held in the long-term as any imports disruption induces preventive measures on the importers side, which allow them reduce energy use or create downward price pressure. In this time perspective, disruption seems to have an adverse, backward connection on exporters' credibility as suppliers, their market shares and export profits. This is mainly visible in the form of imports' diversification and R&D efforts aimed at employing alternative energy sources or energy-efficient technologies. Recognizing this effect, may bring a reflection on the omnidirectional nature of disruption externality.

Due to the fact that this paper investigates the problem only from theoretical economic perspective, caution must be exercised. The interdisciplinary approach or empirical analysis may give additional insight into the problem. The authors also believe that the energy security externality picture may be incomplete as literature is silent about positive externality perspective and means of internalizing external costs. Therefore, those areas are suggested as future research targets.

Summary

Energy security is one of the most frequently analyzed phenomena in the energy markets. The presented paper is of the theoretical nature and focuses on showing energy security externalities. Critical literature review shows the literature mainstream in which energy security externalities are depicted from the point of energy imports and disruption costs, in particular. The majority of identified externalities are of pecuniary nature, which means that they are not a symptom of market inefficiency. The paper also presents selected measures that aim at externality capturing.

References

Ang et al. 2015 – Ang, B.W., Choong ,W.L. and Ng, T.S. 2015. Energy Security: Definitions, Dimensions and Indexes. *Renewable and Sustainable Energy Reviews* No. 42, pp. 1077–1093.

American Research Council (2009). Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. [Online] http://www.ourenergypolicy.org/wp-content/uploads/2012/06/hidden.pdf [Accessed: 2019-09-26].

Bhattacharyya, S.C. 2011. *Energy Economics. Concepts, Issues, Markets and Governance.* London: Springer.

Bohi, D.R. and Toman, M.A. 1996. *The economics of energy security*. Boston: Kluwer Academic Publishers (first edition).

Broadman, H.G. and Hogan, W.W. 1988. Is and Oil Import Tariff Justified? An American Debate: 28 The Numbers Say 'Yes'. *The Energy Journal* No. 9, pp. 7–29.

Budnikowski, A. 2006. International economics (*Międzynarodowe stosunki gospodarcze*). Warszawa: PWE (III edition), 469 pp. (*in Polish*).

Egging et al. 2009 – Egging, R., Holz, F., Von Hirschhausen, Ch. and Gabriel, S. 2009. Representing Gaspec with the World Gas Model. *The Energy Journal*, Special Issue „World Natural Gas Markets and Trade: A Multi-Modeling Perspective", pp. 97–117.

Externe-Pol 2005. [Online] https://pdfs.semanticscholar.org/0377/4c61e622febf384117bd37d4db3796f9ee9e.pdf. [Accessed: 2019-09-26].

Gabriel et al. 2012 – Gabriel, S.A., Rosendahl, K.E., Egging, R., Avetisyan, H.G. and Siddiqui, S. 2012. Cartelisation in gas markets: studying the potential for a "Gas OPEC". *Energy Economics* Vol. 34, Iss. 1, January 2012, pp. 137–152.

Garbicz, M. and Staniek, Z. 2010. Microeconomics. Market failure problems (*Mikroekonomia. Problemy zawodności rynku*). Warszawa: Wydawnictwo Wyższej Szkoły Menedżerskiej w Warszawie, 212 pp. (*in Polish*).

Greene, D.L. and Leiby, P.N. 2006. The oil security metrics model: A Tool for Evaluating the Prospective Oil Security Benefits of DOE's Energy Efficiency and Renewable Energy R&D Programs. Oak Ridge National Laboratory, May 2006. 119 pp.

Golombek et al. 2014 – Golombek, R., Irarrazabal, A.A. and Ma, L. 2014. Opec's market power: An empirical dominant firm model for the oil market. *Working Paper Norges Bank Research* No. 3, pp. 1–42. [Online]: http://www.norges-bank.no/contentassets/fb046e5148f44005a335605d1ae5f899/norges_bank_working_paper_2014_03.pdf [Accessed: 2019-06-25].

Hardin, G. 1968. The Tragedy of the Commons Science. *Science* Vol. 162, no. 3859, pp. 1243–1248. [Online]: http://www.jstor.org/stable/1724745 [Accessed: 2019-09-26].

Hedenus et al. 2010 – Hedenus, F., Azar, C. and Johansson, D.J.A. 2010. Energy security policies in EU-25 – The expected cost of oil supply disruptions. *Energy Policy* No. 38, pp. 1241–1250.

Howard, M. 2001. Public sector economics for developing countries. Kingston: University of West Indies Press. 318 pp.

Huntington, H.G. 2004. Shares, gaps and the economy's response to oil disruptions. *Energy Economics* No. 26(3), pp. 415–424.

IEA 2020. [Online] https://www.iea.org/areas-of-work/ensuring-energy-security [Accessed: 2019-12-30].

Leiby et al. 1997 – Leiby, P.N., Jones, D.W., Curlee, T.R. and Lee, R. 1997. An Oil Imports: An Assessment of Benefits and Costs. Oak Ridge National Laboratory. [Online] http://www.esd.ornl.gov/eess/energy_analysis/files/ORNL6851.pdf [Accessed: 2015-04-25].

Leiby, P.N. 2007. Estimating the Energy Security Benefits of Reduced U.S. Oil Imports. Oak Ridge National Laboratory. [Online] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.169.2384&rep=rep1&type=pdf [Accessed: 2019-09-26].

Mankiw, G. and Taylor, M.P 2006. *Microeconomics*. London: Thomson, 474 pp.

Markandya, A. and Hunt, A. 2004. The externalities of energy security (Externe-Pol No. final report) (pp. 1–34). UK: Bath University. [Online] http://www.externe.info/externe_2006/expolwp3.pdf [Accessed: 2019-09-25].

Metcalf, G. 2013. The economics of energy security, NBER Working Paper Series, 19729. [Online] https://www.nber.org/papers/w19729.pdf [Accessed: 2019-09-25].

Nyga-Łukaszewska, H. 2009. Can the main gas producers' agreement become an OPEC style organisation in the international gas market? (*Czy porozumienie głównych producentów gazu ma szanse stać się nowym OPEC w światowym handlu gazem ziemnym?*). *Zeszyty Naukowe Kolegium Gospodarki Światowej SGH* No. 26, pp. 127–148 (*in Polish*).

Nyga-Łukaszewska, H. 2019. Energy security in the international gas market (*Bezpieczeństwo energetyczne na międzynarodowym rynku gazu ziemnego*). Warszawa: Oficyna Wydawnicza SGH, 148 pp. (*in Polish*).

Paoli et al. 2016 – Paoli, L., Sacco, M. & Pochettino, N. 2016. *Evaluating Security of Energy Supply in the EU: Implications for project appraisal*. [Online] https://institute.eib.org/wp-content/uploads/2016/04/2010BocconiStarebei.pdf [Accessed: 2019-09-26].

Papandreu, A.A. 1998. *Externality and Institutions*. Oxford: Clarendon Press, 304 pp.

Parry, I.W.H. and Darmstader, J. 2003. The costs of US oil dependency. Resources for the Future. Discussion Paper 03–59. [Online] https://pdfs.semanticscholar.org/4deb/8d7bccd001cbd76896cbdc63fa3d4d2675b6.pdf [Accessed: 2019-09-26].

Silvestre, J. 2012. *Public microeconomics. Efficiency and Equity in Public Policy*. Cheltenham: Edward Elgar Publishing Limited, 224 pp.

Stiglitz, J. and Rosengard, J. 2015. *Economics of the public sector*. New York: W.N. Norton&Company. Inc. (fourth edition), 960 pp.

Honorata Nyga-Łukaszewska

Bezpieczeństwo energetyczne w kontekście efektów zewnętrznych – opis zjawiska

Streszczenie

Bezpieczeństwo energetyczne jest jednym z najczęściej analizowanych zjawisk na rynkach energii. Dotychczasowe badania nie są jednoznaczne w zakresie tego, czym jest bezpieczeństwo energetyczne. Z uwagi na fakt, że bezpieczeństwo energetyczne jest analizowane przez różne dziedziny i dyscypliny nauki, badania dostarczyły kompleksowej refleksji na temat tego zjawiska.

Główny cel tego artykułu ma charakter teoretyczny i koncentruje się na pokazaniu efektów zewnętrznych związanych z bezpieczeństwem energetycznym. Autorka dokonuje przeglądu literatury, koncentrując się na istniejącej literaturze odnoszącej się do analizowanych zjawisk. Bezpieczeństwo energetyczne jest jednak badane wyłącznie z punktu widzenia ekonomii, dlatego badania interdyscyplinarne są poza zakresem analizy. Przyczyną dla przyjęcia takiej perspektywy badawczej jest przekonanie, że każda dyscyplina jest inna pod względem koncepcji, metod badawczych i uzyskanych wyników. Dlatego, nie podważając wysokiej wartości interdyscyplinarnych podejść do bezpieczeństwa energetycznego, autorka postanowiła skoncentrować się wyłącznie na perspektywie ekonomicznej. Takie podejście pomaga uzyskać przejrzystość teoretyczną analizy.

Prezentowany artykuł ma charakter teoretyczny i koncentruje się na pokazaniu efektów zewnętrznych związanych z bezpieczeństwem energetycznym. Krytyczny przegląd literatury pokazuje główny nurt literatury, w którym efekty zewnętrzne związane z bezpieczeństwem energetycznym są przedstawione w szczególności z punktu widzenia importu energii i kosztów zakłóceń. Większość zidentyfikowanych efektów zewnętrznych ma charakter pieniężny, co oznacza, że nie są one objawem nieefektywności rynku. W pracy przedstawiono również wybrane środki mające na celu uchwycenie efektów zewnętrznych.

Słowa kluczowe: bezpieczeństwo energetyczne, efekty zewnętrzne, rynek gazu ziemnego