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Shale gas in Poland: An analysis of tax mechanisms and dynamic interactions

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Abstract

This is a preliminary research into possible taxation mechanisms for firms that will be operating in the shale gas industry in Poland and potential market interactions between the incumbents and the entrants. The study places focus on the level of welfare and it includes a static and a dynamic analysis. The result of the former is that the lump sum tax is the first best of all considered tax mechanisms for the Polish shale gas from the welfare perspective. The second best option for taxation is a combination of the current CIT rate and a windfall profit tax. In respect to the dynamic analysis, the results suggest that Gazprom can remain the market leader in Poland even if the shale gas producers start to operate, due to the sequential character of the competition in the Polish natural gas market. Counterintuitively, it will not come at the expenses of the consumers in Poland and it can bring potential welfare gains.

Keywords: Shale gas, Poland, tax mechanism, dynamic game, regulation.

JEL Classification: L10, L95, L98.

Introduction

To date, not a single cubic meter of shale gas has been extracted and sold in Europe. While the substance still sits deep in the ground, it has already fuelled a fierce debate, protests, hopes and fears across the continent. Poland is the forerunner of exploration of natural gas from unconventional (shale rock) deposits. Nevertheless, little economic research has been conducted on the topic of shale gas in Poland. This exploratory study hopes to contribute to the scholarship on the topic.

The aim of this article is to approach the study of shale gas from an economic perspective, with welfare at the centre of the analysis, and to deliver policy recommendations for the Polish government on the taxation of the shale gas extracting firms in Poland.

The key result of the static analysis is that is that lump sum tax is the first best of all taxation methods. The second best option for taxation is a combination of the CIT and a windfall profit tax. From the dynamic perspective, this research argues that Gazprom can remain the market leader thanks to the sequential character of the competition in the Polish natural gas market, but this would not have negative welfare effects.

This study is structured in the following way: section two introduces the topic of shale gas in Poland, section three elaborates on the methods, section four provides an analysis of the tax mechanisms from a static perspective, section five looks at the dynamic effects and sections six concludes the research.

1. Shale gas in Poland

The Polish government initially offered the licenses to explore, or explore and extract, shale gas in the form of concessions. The second license type, to explore and extract, was introduced in order to simplify the market regulation and to attract investors. For a low price firms could purchase the right to explore and extract, regardless of the findings. Concessions are individual parcels of land. The price of each concession is determined by its size multiplied by a single rate that the Polish government sets per square kilometre (km²). A single rate applies to all concessions in the country. For exploration only, the price per km² had been set at PLN 105.81¹ and for exploration and extraction PLN 211.62². In addition, the firm that bought the license only for the exploration process had the pre-emptive right to upgrade the license to extraction of shale gas. There were two reason behind this design. First was lack of knowledge about the quantity and quality of natural gas in the Polish shale rock formations. Second, the investors, not the taxpayers, bore the cost of exploration and the associated risk. Shifting the costs and risk associated with exploration process on investors was compensated by the government to the firms in the form of the pre-emptive right to purchase a license for extraction and the single exploration/extraction licenses. A new law, introduced in 2014, has combined previous types of concession into one, in a further effort to simplify access to the market. In all cases the legal set-

¹ EUR 25.00.

² EUR 50.00.

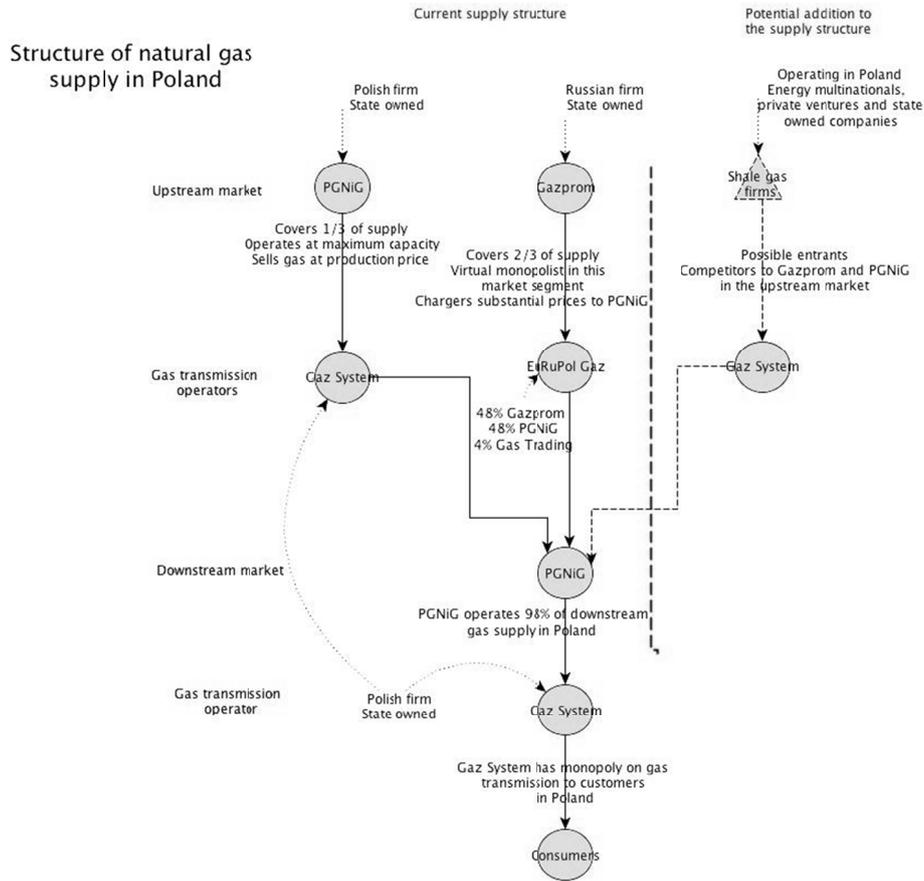
up has ruled out auctions at the extraction stage. For this reason the Polish government has turned to taxation as a method to collect revenue from the potential shale gas extraction and sales. In the Polish government's view the 19 per cent profit tax is insufficient. Warsaw decided, in the 2014 change of law, to raise the potential revenue from taxation of shale gas firms by adding a complementary tax on fossil fuels, that depends on the profitability of the source, and can amount to 0, 12,5 or 25 per cent and also an additional tax of 1,5 per cent on the total value of extracted natural gas from shale sources. Nevertheless, collection of the complementary tax has been suspended until year 2020, in an attempt to stimulate the industry. Possibly, taxation of shale gas will be adjusted once again in the future. Without certainty about tax regulation and the size of the tax burden, investors are reluctant to invest in exploration or move from exploration to extraction; what harms consumers of natural gas in Poland.

The structure of the supply of natural gas in Poland is the second reason, next to revenue, for the Polish government to give substantial attention to shale gas. PGNiG, the Polish state-owned gas company, operates in both the upstream and downstream market in Poland. In the upstream market it has the monopoly to extract conventional deposits of natural gas in Poland. But, it can only meet one third of Polish gas demand due to limited resources. The remaining two thirds are supplied by Gazprom, a Russian state-owned firm. Gazprom has a virtual monopoly over the demand not covered by the domestic production from PGNiG in the upstream market. Gazprom delivers the end product, natural gas, to PGNiG via the Yamal-Europe pipeline. It is the sole owner of the pipeline on the Russian and Belarusian territory. In Poland the Russian firm manages the network together with PGNiG. Both state monopolists have 48 per cent of shares, remaining 4 per cent belongs to Gas-Trading S.A. (largely owned by PGNiG). Both firms, Gazprom and PGNiG, sell natural gas to the distribution arm of PGNiG, which then sells it to the Polish consumers. The final price is a combination of Gazprom's price for PGNiG, production cost of PGNiG at which it sells gas to its distribution arm and fees of the gas transmission from Gaz-System, state-owned too. In Poland PGNiG operates 98 per cent of sales to final consumers [BRE Bank 2012].

Entry of firms extracting natural gas from unconventional deposits in Poland would reduce the dominant position of Gazprom in the upstream supply market for natural gas – a change that Polish authorities would gladly welcome.

Figure below provides an overview of the market.

Figure 1. Natural gas market in Poland



2. Methodology

My research puts emphasis on the potential market structure and impact of the number of firms in the natural gas market on price and quantity. In the static analysis, I assume that firms compete in a Cournot fashion. Let us consider a Cournot model, where competition takes place in quantity, with many firms.

Below, I list the assumption about the firms. Constant marginal cost at c and we omit fixed cost (it will be considered in the later part of this research).

Quantity is described by Q , where $Q = q_i + Q_{-i}$ and q_i is the quantity produced by firm i and Q_{-i} describes the competitors, e.g. for three other firms we will have $Q_{-i} = q_{i+1} + q_{i+2} + q_{i+3}$.

Price is equal to $P(Q) = A - BQ$, therefore $P(Q) = A - B(q_i + Q_{-i})$.

Profit is described by the following function: $\pi_i = [P(Q) - c] * q_i$,

therefore $\pi_i = [(A - B(q_i + Q_{-i}) - c) * q_i$.

The first order condition for profit maximisation is equal to:

$$d\pi_i / dq_i = A - c - BQ_{-i} - 2Bq_i = 0.$$

After rewriting the first order condition we receive firm's i quantity decision (best response): $q_i = [(A - c) / (2B)] - (Q_{-i} / 2)$.

In a symmetric model we use $Q_{-i} = (N - 1)q_i$, so the best response can be transformed to: $q_i = [1 / (N + 1)] * [(A - c) / B]$.

What follows is: $Q = [1 / (N + 1)] * [(A - c) / B]$.

Thus, the perfectly competitive outcome in Cournot setting is described by $Q = [(A - c) / B]$.

A monopolist will produce exactly half of the perfectly competitive outcome, because $N = 1$, therefore $Q = 1/2 * [(A - c) / B]$.

Hence, the greater the number of firms N the closer we are to perfect competition; resulting in the highest possible consumer surplus, since price converges towards firms' marginal cost.

2.1. Details about the four tax mechanisms

I consider four tax mechanisms that are at the Polish government's disposal. A profit tax (CIT), a quantity tax, a lump sum tax and a windfall profit tax. The table below gives a summary of specifications for each tax.

Table 1. Summary of the tax mechanisms

Tax mechanism	Short description	Related difficulties	When works best
Profit tax	Levied on earnings reported by a firm	Firms can overstate costs Firms can engage in tax optimisation	When tax collection quality is achieved by the responsible institution
Quantity tax	Tax per unit	Alters profit function reducing quantity and increasing price	Quantity sold is easily observable
Lump sum tax	One-off lump sum payment	Accurately estimating size of an optimal lump sum tax	The value of a gas field can be precisely determined
Windfall profit tax	Tax for sales above base rate price	When base rate differs from firms' marginal costs the tax alters firms' profit function	Marginal costs are easily observable and do not vary across the industry

2.2. Analytical framework: The three assessment criteria

In my analysis, I decided to use three criteria to assess the expected performance of the four tax mechanisms: quantity produced, number of firms and tax specific difficulty. The first two criteria put a joint emphasis on welfare, with

particular interest in consumer surplus and deadweight loss. The third criterion is a practical aspect of each tax mechanism:

Criterion 1: Quantity produced.

When a tax enters firm’s marginal cost structure it alters the optimal quantity produced, consequently changing the equilibrium price and quantity by increasing the former and reducing the latter, so it increases the deadweight loss and reduces consumer surplus [Pepall, Richards & Norman 2011].

Criterion 2: Number of firms.

When firms compete in Cournot fashion, in other words in quantity, and we assume no entry costs, in such case an increase in number of firms brings the equilibrium price and quantity towards the competitive outcome (price equal to marginal cost), what in turn increases consumer surplus [Corchon, 2008].

Criterion 3: Tax Specific Difficulties.

This is the practical side of the problems related to each tax mechanisms. I discuss expected difficulties related to implementation and operation of each of the four tax mechanisms within the Polish context.

3. Static analysis

Table 2 represent the results of the test of four tax mechanism for shale gas extraction against the criteria discussed in the previous section.

Table 2. Results of the static analysis

Tax mechanism	Quantity produced	Number of firms	Tax specific difficulties
Profit tax	There are no effect on the quantity produced	An increase in the profit tax rate has a negative effect on the firm’s entry decision Empirics suggest no relation between change in CIT and firms’ exit	The key problem in Poland is tax optimisation
Quantity tax	The quantity tax has negative impact on the quantity produced	The quantity tax, if high, can have small effect on the number of firms in the short run but strong effect in the long run	No concerns related to the quantity tax because PGNiG is responsible for all distribution of natural gas in Poland
Lump sum tax	The tax has no effects on the quantity produced	The tax has no effect on the number of firms if its size is not equal or greater than firms’ profits	The Polish tax authority has to correctly asses the size of the lump sum and ROV is a method that can be employed
Windfall profit tax	No distorting effect on quantity if the base rate price is equal to firms’ marginal costs	There is a possible combination of tax rate and base rate price (below or equal to marginal cost) that can have effect on firms’ exit and entry decision	Technology is homogenous and spill-overs are wide The marginal cost structure can be observed Cost heterogeneity will be determined by location

3.1. Profit tax

Profit tax is levied on firm's earnings, which are net benefits of firm's operation [Eccles et al. 2001]. For example, a firm has earned \$10 by selling one unit at a price of \$10, its marginal cost is equal to zero and fixed cost amount to \$5, the profit of this imaginary firm is therefore \$5. For a profit tax rate of 20 per cent, in this imaginary economy, the firm has to give \$1 to the tax authority. In Poland the CIT is set at 19 per cent.

Recommendation and summary

If the Polish tax authority would like to increase the profit tax as a part of the tax scheme it would have to:

- Consider the potential adverse effects on firms' entry decision and tax optimisation strategies as firms' solution to an increase in the CIT.
- Examine introducing an additional tax mechanism, in order to achieve the desired taxation level without changes in the current CIT.
- Empirical studies suggest no relation between firms' exit decision and CIT; this aspect requires further study.

Quantity produced in a static setting

I would like to employ the model used in the methodology section and recall that: $q_i = [(A - c) / (2B)] - (Q_{-i} / 2)$.

For the profit tax let us use the following specification:

Size of the profit tax is equal to $(1 - \alpha) * 100\%$, where $0 \leq \alpha \leq 1$, i.e. for a profit tax of 20% the coefficient α has to be equal to 0.8

$$(1 - 0.8) * 100\% = 20\%.$$

The firm keeps the remaining part of the profit, the α share.

Let us consider the effect of the profit tax on the quantity produced.

The profit function has to be adjusted for the tax, we receive the following equation:

$$\pi_i = [(A - B(q_i + Q_{-i}) - c) * q_i] * \alpha.$$

Firm i keeps only the α share of its profits.

The first order condition follows:

$$d\pi_i / dq_i = (A - c - BQ_{-q} - 2Bq_i) * \alpha = 0.$$

After rewriting the first order condition we obtain:

$$q_i * \alpha = [(A - c) / (2B)] - (Q_{-i} / 2) * \alpha.$$

Dividing both side of this equation by α results in:

$$q_i = [(A - c) / (2B)] - (Q_{-i} / 2).$$

Which is identical to the quantity decision without any tax. **Therefore, from the theoretical perspective the profit tax has no impact on the firm's production decision.** A firm cannot improve its situation when the profit tax is introduced by changing the quantity decision, its best response is to produce as if the profit tax has not been introduced. This gives a degree of confidence in suggesting that the profit tax has no impact on firms quantity decision. Therefore, in a Cournot setting, in our simple static analysis, it has a neutral effect on consumer surplus, as the price and quantity relation does not change.

Number of firms

Economic intuition suggests that increasing the profit tax, or in other words lowering the premium earned on operating the firm, or simply increasing costs, can influence firms' entry decision. Academic literature bridges the economic intuition and reality in relation to assumptions about firms' entry and exit in relation to the level of the profit tax. According to Da Rin [Da Rin, Di Giacomo & Sembenelli 2010], the CIT rate has a statistically significant effect on firms entry decision. His study for European countries between 1997 and 2004 shows a negative non-linear relation between the two. A similar study on OECD countries by Kneller and McGowan [2012] supports the claim of a negative relation between firms' entry and CIT level. These results are relevant for the concessions that have not been sold to date. If the diversification of supply of natural gas in Poland and use of full potential of Polish shale gas reserves are priorities for the government, the Polish tax authority ought to be considerate on a potential CIT increase.

In relation to firms exit, some have already left Poland. "The Economist" (2013) claims that the underlying reason was messy regulation for exploration and extraction of unconventional fuels and slow pace of work on the final tax scheme at the Polish Ministry of Finance. From the economic perspective, an empirical study by Kneller and McGowan [2011] could not find a relation between increase in CIT rate and firms exit among OECD countries. It seems, however, to be a very strong assumption. If tax are to be treated as a cost, increasing CIT at a particular rate should result in firms exit. This would require further studies, especially in relation to the extractive industry. This leaves the Polish tax authority in a situation where an increase in the rate of CIT can push firms into tax optimisation which is a legal but costly operation to reduce firm's tax burden. It is particularly plausible for shale gas because firms are bounded to the gas field. Therefore, an increase in the CIT rate could result in lower than expected increase in revenue for the Polish treasury because firms can turn into

tax optimisation practices. In particular, if the cost of such operation will be lower than the increase of the tax burden.

The Polish tax authority has to consider potential adverse effects of an increase in the profit tax on entry decision. Not all concessions have been sold and if it is the government's priority to have all concession operating, an increase in CIT can obstruct it. An increase in the CIT rate might not lead to firms' exit from Poland, unlike lack of confident shale gas tax regulation, but it can push firms into tax optimisation practices.

Tax specific difficulty

Because outright illegal tax evasion is a crime, measuring the size of it is difficult. We only know about reported cases, but it does not necessarily reflect the full picture. The same holds true for legal tax evasion, in other words tax optimisation. It is hard to assess the scale of the problem, how it compares to other countries and how much companies do (not) pay. Most studies claim that the compliance level for CIT in Poland is on par with other EU and OECD countries. But the current problem, to an extent global, is tax optimisation by firms. One aspect that assures high level of compliance is the low CIT rate in Poland, currently set at 19 per cent, one of the lowest among OECD countries.

This claim is in line with economic intuition, if we think of taxes as costs. Low CIT removes the incentives for firms to engage in activities that will reduce this burden, i.e. tax optimisation, as such operation are expensive too (e.g. lawyers, consultants). This translates to a difficulty for the tax authority. An increase in the CIT rate can push firms to engagement with tax optimisation that will assure lower effective rate. This can result in increased costs for the firms (e.g. money spend on tax consulting), the tax office (e.g. additional spending on auditing) and lower than expected revenue from the tax hike. The desired level of taxation can be alternatively achieved by the tax authority through introduction of a complimentary tax mechanism (e.g. windfall profit tax) next to the profit tax. This is the most common tax scheme among oil and gas exporting countries [Ernst & Young 2011] and is used by Norway for example.

3.2. Windfall profit tax

Windfall profit tax applies to transactions that occur above a base rate price, set by the authority, and is levied only on the earnings generated from such transactions. For example, if the base rate price is set at \$4, windfall profit tax is set at 50% and a sale of one unit at a price of \$8 took place, the firm is subject to \$2 of the windfall profit tax.

Recommendation and summary

If the Polish tax authority would like to introduce the windfall profit as a part of the tax scheme it would have to:

- Create a body responsible for assessment of extraction cost.
- Set the base rate price per geographical region.
- Observe progress in the industry's technology and spill-overs.
- Asses the level of accuracy of the extraction cost predictions.

Quantity produced

I would like to employ the model used in the methodology section and recall that: $q_i = [(A - c) / (2B)] - (Q_{-i} / 2)$.

For the windfall profit tax let us use the following specification:

size of the profit tax is equal to $\alpha * 100\%$, where $0 \leq \alpha \leq 1$.

For a windfall profit tax of 80% the coefficient α has to be equal to 0.8. P^* is the base rate price set by the tax authority, and $P_c = P(Q) = A - B (q_i + Q_{-i})$ is the current price.

The size of the tax to be paid by a firm to the authority is described by the following equation: $[(P_c - P^*) * q_i] * \alpha$.

Let us consider the effect of the windfall profit tax on the quantity produced. The profit function has to be adjusted for the tax:

$$\pi_i = [[(A - B (q_i + Q_{-i}) - c) * q_i] - [(A - B (q_i + Q_{-i}) - P^*) * q_i] * \alpha.$$

Let us first consider a case with $P^* = c$, the base rate equal to marginal cost:

$$\pi_i = [[(A - B (q_i + Q_{-i}) - c) * q_i] - [(A - B (q_i + Q_{-i}) - c) * q_i] * \alpha.$$

This can be simplified to:

$$\pi_i = [[(A - B (q_i + Q_{-i}) - c) * q_i] * (1 - \alpha).$$

Firm i keeps only the $(1 - \alpha)$ share of its profits.

The first order condition that follows:

$$d\pi_i / dq_i = (A - c - BQ_{-i} - 2Bq_i) * (1 - \alpha) = 0.$$

After rewriting the first order condition we obtain:

$$q_i * (1 - \alpha) = [(A - c) / (2B)] - (Q_{-i} / 2) * (1 - \alpha).$$

Dividing both side of this equation by $(1 - \alpha)$ results in:

$$q_i = [(A - c) / (2B)] - (Q_{-i} / 2).$$

Therefore, **if the base rate price (P^*) is equated to the marginal cost (c), the tax has no effect on quantity produced**, and like in the case of the profit tax, the firm's best response is to produce as if the tax has not been introduced.

Let us consider an example when the base rate price is different to marginal cost: $\pi_i = [(A - B(q_i + Q_{-i}) - c) * q_i] - [(A - B(q_i + Q_{-i}) - P^*) * q_i] * \alpha$.

The first order condition is:

$$d\pi_i / dq_i = (A - c - BQ_{-q} - 2Bq_i) - (A - c - BQ_{-q} - 2Bq_i - P^*) * \alpha = 0.$$

What simplifies to: $q_i = [(A - c) / (2B)] (Q_{-i} / 2) [(P^*) * \alpha / (2B - 2B\alpha)]$.

What in turn is smaller than $[(A - c) / (2B)] - (Q_{-i} / 2)$ that we obtained in the case of marginal cost equal to the base rate price. Hence, a base rate for windfall profit tax different than firm's marginal cost, has negative impact on the quantity produced by the firm. What in Cournot competition leads to higher price and consequently loss in consumer surplus. **The capacity of the authority to determine the marginal cost structure is crucial in respect to the quantity produced criterion.** Without such knowledge the tax authority, by implementing windfall profit tax, can cause possible inefficiencies in quantity and negative price disruptions, what will lead to a negative effect on the consumer surplus.

Number of firms

There are two cases worth to consider in relation to the number of firms in the market. First, if the base rate is equated to the extraction cost. Second, if it is set below the extraction cost. In regard of the former, base rate equal to extraction costs, the windfall profit tax effectively works as a profit tax and the same principles apply. Set at 100% leaves a firm with profit equal to zero. The difference, however, is in the compliance process – the tax authority can observe the price and quantity of gas sold, therefore a firm can only reduce its tax burden by lowering the extraction cost. In regard of the latter, when the base rate price is set below the firm's extraction cost, the following applies:

$$\text{If } (P_c - c) * q_i \leq [(P_c - P^*) * q_i] * \alpha \text{ then } \pi_i \leq 0,$$

therefore, profit will equal zero if $(P_c - c) * q_i = [(P_c - P^*) * q_i] * \alpha$.

In this instance, the firm is worse off, or at best indifferent, while operating.

Consequently, the authority has to carefully consider setting the base rate price and the windfall profit tax rate because it is possible to create a combination that can leave a firm with negative profits. There are two possible scenarios in this case:

1. For many firms with different extraction cost:
 - the most cost efficient firms will stay in the market, if there is one base rate price;
 - complex tax system in which each firm has its own base rate price.
2. For many firms with homogenous extraction cost:
 - the whole industry can be jeopardised or stop operating.

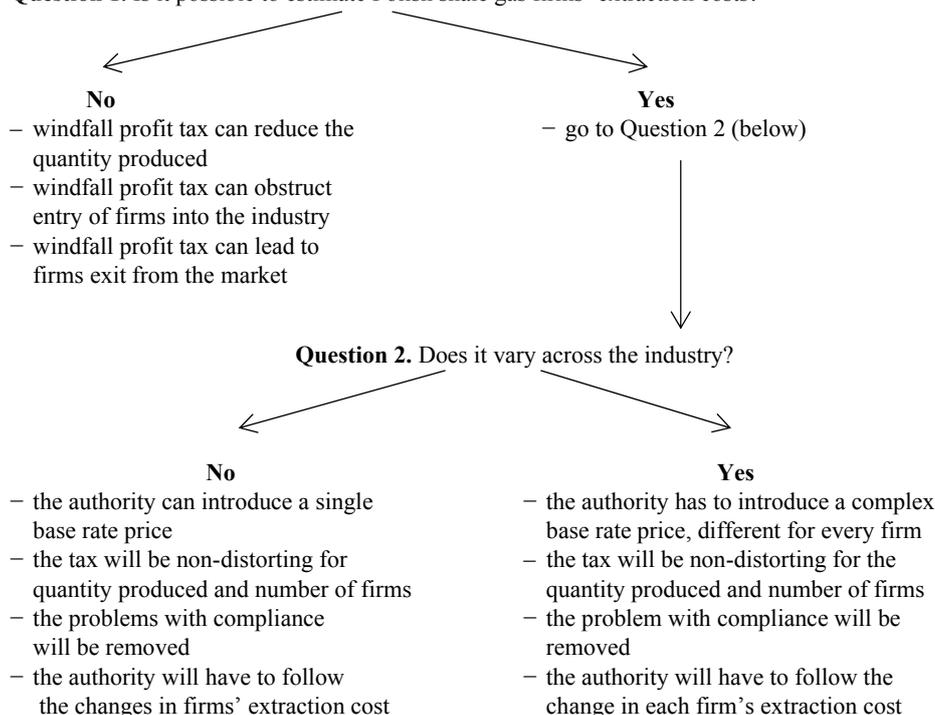
The character of the extraction cost is crucial for the number of firm criterion. Without the knowledge about the extraction cost and its character – homogeneous or heterogeneous – across the industry, the tax authority has no foundation for a base rate price. This will result in introduction of a tax mechanism that can affect the number of firms in the industry or even jeopardise the industry’s development.

Tax specific difficulty

The ability of the tax authority to determine the extraction cost and its character across the industry emerged as the key aspect for the windfall profit tax. Therefore, this section is devoted to the tax specific difficulty, the extraction cost for shale gas in Poland and its character across the Polish industry. The scheme below presents the possible outcomes.

Figure 2. Windfall Profit Tax and extraction costs of shale gas

Question 1. Is it possible to estimate Polish shale gas firms’ extraction costs?



Qualitative approach to the extraction costs structure

I conducted a set of interviews with the Polish Geological Institute in order to gather information on the potential costs of shale extraction in Poland. The institute is a body related to the Polish Academy of Science, not engaged with any of the operating firms. The general conclusions from the interviews are following:

1. Extraction (marginal) cost of shale gas extraction in Poland are higher (two to three times) than in the US, but the technology is changing.
2. The tax authority is capable to determine the extraction cost structure across firms and regions in the Polish shale gas industry.
3. Changes in technology in the extraction industry have large spill-over effect, therefore the tax authority can easily observe potential changes.
4. The heterogeneity of extraction cost is related to geographical location, it is not a firm specific aspect.
5. Base rate price can be determined at extraction cost level, but will have to be set by the Polish tax authority according to regions.

3.3. Lump sum tax

Lump sum tax is a one off payment levied on firms. For example, let us consider a one period scenario, with the lump sum tax set at \$5,000 and an imaginary firm that has a profit of \$4,000. After the tax deduction this firm will have a (negative) profit of -\$1,000 for the discussed period.

Recommendation and summary

If the Polish tax authority would like to introduce the lump sum tax as a part of the tax scheme it will have to:

- Prepare a Real Option Value (ROV) model for assessment of the concession value.
- Check the data provided by firms on ROV components.
- Supervise the process of tax collection and firms' field extraction/suspension decisions.
- Prepare a roadmap (Figure 3 is an example that I created) of the lump sum tax collection process.

Quantity produced

I would like to employ the model used in the methodology section and recall that: $q_i = [(A - c) / (2B)] - (Q_i / 2)$.

For the lump sum tax let us use the following specification: Size of the lump sum tax is equal to L , where $L > 0$, i.e. a lump sum tax of \$5,000, in other words $L = 5,000$.

Let us consider the effect of the lump sum tax on the quantity produced. The profit function has to be adjusted for the tax; thus the following equation:

$$\pi_i = [(A - B(q_i + Q_{-i}) - c) * q_i] - L.$$

The first order condition that follows:

$$d\pi_i / dq_i = (A - c - BQ_{-i} - 2Bq_i) = 0.$$

After rewriting the first order condition we obtain:

$$q_i = [(A - c) / (2B)] - (Q_{-i} / 2).$$

What is equal to the best response without the lump sum tax. The lump sum tax does not have any effect on the quantity produced by firms.

Number of firms

The lump sum tax will not have effect on the number of firms **unless its size is greater than firms' profit**. Therefore, for $L > \pi_i$, firm i will be better-off not producing.

Tax specific difficulty

The advantage of the lump sum tax is that, like in the case of profit tax or windfall profit tax with a base rate set at marginal cost, it does not enter the firm's quantity produced decision. Another advantage is that, unlike the profit tax, firms are not able to reduce their tax burden, and the tax authority does not require knowledge about the firms' extraction cost, what is the case for the windfall profit tax. The associated difficulty, however, is to estimate the size of the lump sum tax correctly. If it is estimated too high it can have negative impact on the number of firms and consequently prices and consumer surplus. Therefore, the Polish tax authority, if it would like to employ the lump sum tax, has to provide correct estimations. Below, a method that can be used to determine the lump sum tax is presented.

The right to explore and extract shale gas in Poland is sold in concessions. A firm can own a single or several concessions. Therefore, the best way to estimate the size of the lump sum tax for an individual firm is per concession(s) it owns. What in turn requires assessment of the value of each concession. By the word value, I understand the potential earnings of a firm from operating at a particular concession. The method under study in this research for the lump sum tax is the Real Option Theory. For long it has been used in finance, but recently it has

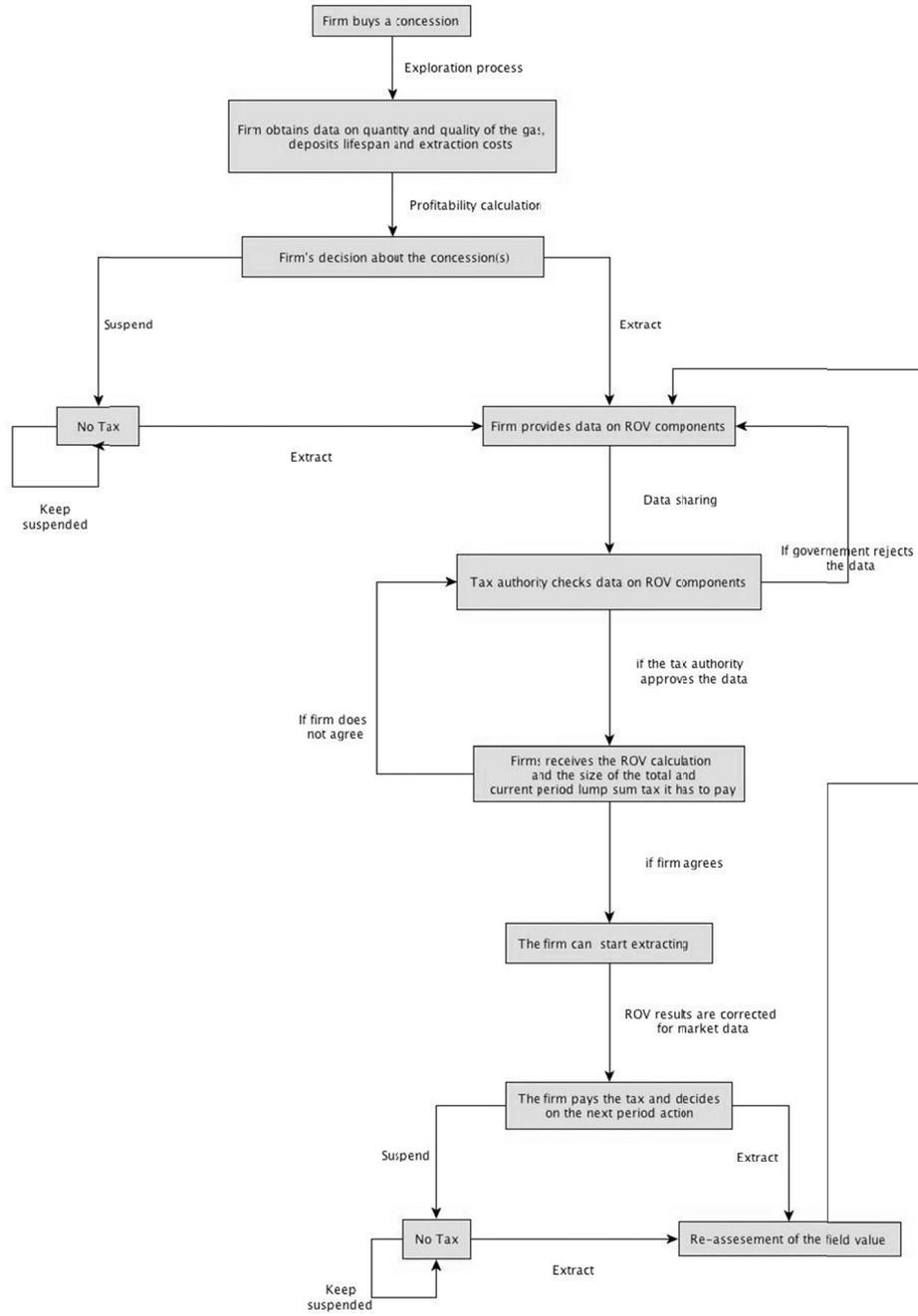
started to attract attention for estimation of “real” or physical as opposed to financial assets [Slade 2001; Broadie & Detemple 2004].

In my view it is the most appropriate method to estimate the size of the lump sum tax for Polish shale gas. First of all, it measures what is necessary for the lump sum tax, namely the value of the concession. Second, it employs data used in the exploration process, what makes the tax very accurate. This is particularly important if the reserves of the Polish shale gas will be lower than expected.

The following figure is a roadmap I have designed to depict the process of exercising the ROV-calculated lump sum tax on the firms operating in shale gas extraction in Poland. According to the Polish Geological Institute the details required for the ROV calculation can be obtained by the Polish tax authority. After data sharing process and concession value assessment, the firm would receive the amount of the lump sum tax it has to pay for its concession(s). This lump sum can be divided into smaller fractions, paid per operating period. If the lifespan of a gas field is assessed to be for example five years, then the lump sum tax can be paid in five instalments. This gives the firm the flexibility to suspend the extraction. The end of period payment or ROV value after restarting a field from suspension should be re-assessed for potential mistakes/corrections in the earlier ROV calculations.

The Polish tax authority would have to develop a model for ROV calculation, and create a body designated for the lump sum tax assessment and supervision of the collection process. Finally, it would have to prepare a compliance roadmap for firms, as in Figure 3.

Figure 3. Compliance roadmap for the ROV-based lump sum tax



3.4. Quantity tax

Quantity tax is levied per unit. For example, if a firm has sold 3 units of a good and the tax per unit is \$2, then the firm is obliged to pay \$6 in tax.

Recommendation and summary

If the Polish tax authority would like to introduce the quantity tax as a part of the tax scheme it will have to:

- Consider that quantity tax is always distorting quantity produced a firm.
- It is the simplest of possible methods and the Polish tax authority is experienced in collecting the quantity tax.

Quantity produced

I would like to employ the model used in the methodology section and recall: $q_i = [(A - c) / (2B)] - (Q_{-i} / 2)$.

For the quantity tax let us use the following specification. The size of the quantity tax is equal to v , where $v > 0$, i.e. for a quantity tax equal to \$3 the amount collected by the authority (and deduced from firm's profit) is equal to $3 * q_i$.

Let us consider the effect of the quantity tax on the quantity produced.

The profit function has to be adjusted for the tax, we receive the following equation: $\pi_i = [(A - B(q_i + Q_{-i}) - c - v) * q_i]$.

Firm i keeps only the α share of its profits.

The first order condition that follows:

$$d\pi_i / dq_i = (A - c - BQ_{-i} - 2Bq_i - v) = 0.$$

After rewriting the first order condition we obtain:

$$q_i = [(A - c - v) / (2B)] - (Q_{-i} / 2).$$

What **results in lower quantity produced than without the tax in place.**

Consequently, in Cournot competition, it leads to higher prices and lower consumer surplus.

Number of firms

I could not find research about the relation of the quantity tax and firms entry/exit into/from an industry. From the theoretical perspective, the quantity tax can affect the number of firms when the size of the tax is so large that it drives out demand for the product. In that case, firms are not able to sell the product and consequently can leave the market. This conclusion has to be adjusted for the elasticity of demand. If the demand is highly inelastic – typically the case in the short run for energy resources – than the size of the quantity tax can be rela-

tively large and the product will still attract demand. In the long run the demand becomes more elastic as firms and consumers turn into alternative sources of energy. In such case the size of quantity tax that will drive out the demand for natural gas is smaller. The shale gas boom in US caused such shift in demand from oil to natural gas, thanks to low prices and large supply of the latter.

Tax specific difficulty

There are no associated difficulties with the quantity tax because it is easy to observe and collect by the Polish tax authority. The sale of natural gas in Poland is organised by PGNiG, a state owned company, and there are no alternative ways to purchase gas from the network. Liquid gas is an alternative way to sell natural gas outside of the network system. However, this would require the shale gas extracting companies to open facilities that will provide this service, what can be easily traced by the Polish tax authority. It is the simplest of all solutions, but on the other hand it brings a distorting effect at every rate, unlike the three other tax mechanisms discussed in this paper.

4. Dynamic analysis

In this section, I first analyse the Stackelberg model of sequential quantity competition, then I turn to dynamic games.

4.1. Stackelberg model

Stackelberg model describes the outcome when firms compete in quantity and decision are taken sequentially, what resembles the market situation if the shale gas firms will decide to begin industrial extraction in Poland. We assume that competition in the natural gas market is in quantity. In addition, Gazprom will benefit from the first mover advantage, because it already signs contracts on a regular basis with the Polish gas distributing monopolist PGNiG.

Economics behind the model

Let us consider a duopoly example of first and second mover with constant marginal cost and linear demanded.

Quantity is described by Q , where $Q = q_1 + q_2$.

Price is equal to $P(Q) = A - BQ$, therefore $P(Q) = A - B(q_1 + q_2)$.

In the Stackelberg setting the second mover, let us assume it is firm two, does not have to guess the output of the first mover. It is only firm one that has to take into account the best response of firm two.

Therefore the profit of firm one is:

$$\pi_1 = [P(Q) - c] * q_1, \text{ therefore } \pi_1 = [(A - B (q_1 + R_2(q_1)) - c] * q_1.$$

Where $R_2(q_1)$ is firm's two best response that is equal to the Cournot duopoly best reply: $q_2 = [(A - c) / 2B] - q_1/2$.

What yields the firm's one optimal quantity decision such that:

$$A - B [q_1 + (A - c)/2B - q_1] - B * (q_1/2) = c.$$

What simplified gives:

$$q_1 = (A - c) / 2B.$$

$$q_2 = (A - c) / 4B.$$

Therefore the total quantity produced in the Stackelberg setting is:

$$Q_{stackelberg} = 3(A - c) / 4B.$$

Which is greater than Cournot duopoly result equals to: $Q_{cournot} = 2(A - c) / 3B$.

This results in **lower prices and higher quantity under Stackelberg duopoly than Cournot duopoly** and consequently **higher total welfare**. According to Pepall [Pepall, Richards & Norman 2001], under the constant marginal cost and linear demand the Stackelberg duopoly realises three-fourths of the total welfare, where Cournot duopoly only two-thirds of the total welfare.

Implication for the Polish shale gas market

The current situation, where Gazprom has monopoly over two-thirds of the Polish natural gas demand, results in the highest prices paid by the Polish consumer for the Russian gas in the European Union. However, entry of a firm that would extract the Polish shale gas deposits and the current method of signing agreements by PGNiG, that creates the sequential game among competitors, could have positive implications for the welfare of Polish consumers.

Another aspect that has to be considered is that in the Stackelberg model the first mover produces much more than the follower, what results in his dominant position. This can happen in the Polish natural gas market after the entry of shale gas extracting firms. Gazprom's position of a leader will not change, but it will not necessarily imply that consumer are worse-off or discriminatory practices are taking place. The reason behind is precisely the character of the sequential competition in quantity.

Finally, this type of competition can alter the decision of the firms extracting gas from shale rocks. This would require further assessment of the lump sum tax. It is possible that firms will decide to decrease the quantity produced from otherwise optimal, given the decision of Gazprom. The end-of-period correction of the actual quantity extracted that appears in the roadmap for ROV implementation (Figure 3) can be a potential solution to this problem.

4.2. Dynamic game

I discuss the game theory matrix under the following assumptions. There will be three potential players in the Polish natural gas market (let us consider firms that will extract gas from the shale deposits as a single firm for simplicity): 1) PGNiG; 2) Gazprom; 3) Shale gas firms.

PGNiG is a state owned company that operates both in the upstream and downstream of the natural gas market in Poland and organises distribution and sales. It sells gas to the downstream market at marginal cost prices, where the final consumers pay a price that combines the imports of natural gas from Gazprom. In other words the upstream division of PGNiG and Gazprom sell gas to the downstream division of PGNiG (former at marginal cost, latter at a contract price), then the downstream division of PGNiG sells gas to individual customers. This consequently allows us for exclusion of PGNiG from the dynamic game analysis because it is only capable to support two-thirds of the Polish demand and does not exactly take part in the competition.

Gazprom in case of entry by shale gas extracting firms has two option: it can either accommodate the entry or start a price war. To accommodate would mean a fall in price and profits for Gazprom, as we concluded in the previous chapters analysing the Cournot and Stackelberg outcome. To fight, would lead to negative profit, as Gazprom would have to price in an aggressive manner, in order to drive the competitors out of the market.

The shale gas extracting firms can make two decision after the exploration process, if they found sufficient amount of gas: start to extract and enter the market or drop out. To extract would lead to low positive profits if the Gazprom accommodates the entry of new firms, and negative profits if the Russian firm decides to fight. If the firms drop out, they will leave with a negative account balance because of the substantial exploration cost. I do not consider the case, when there is not enough gas in a firm's concession(s) because in such case a firm will always drop out.

Table 3. Profit structure in the dynamic game

		Gazprom	
		Fight	Accommodate
Shale gas firms	Enter	negative, negative	low, low
	Drop out	negative, low	negative, high

Therefore, the decision to enter for shale gas firms and the decision to accommodate for Gazprom are sub-game perfect strategies for all firms. In other words, these strategies are optimal for each firm regardless of the decision of the

opponent and the firms would stick to them when the game is repeated. The implication for the Polish shale gas market is that we can assume that firms that are currently in the process of shale gas exploration, given that they have found sufficient quantities for industrial extraction, will decide to enter the market. Gazprom will be better-off to accommodate the entry of new firms, so we can expect that a price war will not take place.

Conclusion and policy recommendations

The key conclusion of this research is that lump sum tax is the first best of all taxation methods. In my opinion it should be calculated using the ROV method. Lump sum is least distorting of the taxes. It also helps to hedge against the risk of “lower than expected” gas deposits in Poland. ROV method gives an accurate description of the field value, what allows for setting optimal taxes regardless of its size. The second best option for taxation is a combination of the current CIT rate and the windfall profit tax. The ability of the Polish government to collect the CIT is considerable. The complimentary tax mechanism, which is the windfall profit tax, can be non-distorting if the base rate price is accurately set at the firms’ extraction cost level. From the dynamic perspective, this research argues that Gazprom can remain the market leader thanks to the sequential character of competition in the Polish natural gas market. Counterintuitively, it will not come at expenses of consumers, but will be the result of sequential competition and can bring potential welfare gains for consumers. Another argument forwarded in this article is that a price war is unlikely to happen between Gazprom and the potential entrants in the natural gas market, which are firms extracting gas from shale rocks. Gazprom will be better-off accommodating the entry of shale gas firms.

I would like to highlight, given the theoretical and explanatory character of this article, the areas for future research. This includes the excessive entry problem, development of a ROV model to assess the value of concessions and research on extraction cost faced by firms that will be operating in the Polish shale gas market. Moreover, the current market structure can endanger transfer of benefits from increased competition in the upstream market to the Polish consumers [UOKiK, 2011].

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