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Global Shale Revolution: Successes, Challenges, and Prospects

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Abstract: This study reveals the current problems and prospects of developing shale oil and gas industries in the USA, Canada, Mexico, Poland, Russia, China, India, and Australia. This approach allows a comprehensive and wide view on the industry and its geography. A brief review of the technologies implemented in the shale industry is provided. The key aim of the paper is to compare the hydrocarbon market conjuncture and economic environment (including financial), in the above-mentioned states, in order to reveal the factors contributing to the development of the industry. The methodology is based on the statistical estimation of the extraction, exports, and reserves of extractable shale hydrocarbons. The analysis given allows the forecast and estimation of the economic effects and external institutional effects of shale hydrocarbon extraction. It also contributes to the evaluation of the prospects of shale industry development in America, the EU, Russia, and the Asia-Pacific region. In accordance with the overall impact the shale revolution has had on the economies, environmental conditions, and societies of the chosen countries, recommendations are provided. The authors develop three scenarios for the future of the shale industry. The most probable scenario is a slower dissemination of horizontal drilling, as well as tight oil and shale gas extraction, with the decline of conventional reserve volumes.

Keywords: shale revolution; shale oil and gas; horizontal drilling; economy; ecology

1. Introduction

When we speak of the "shale revolution" in this article, we refer to a bundle of technologies which can foster the extraction of oil and gas from shale rock, impermeable mudstone, or siltstone. Two main technologies used in extracting these natural resources from high-pressure collectors are horizontal drilling and hydraulic fracturing (fracking). The fundamental research on the history of oil and gas, by Yergin [1], demonstrated that the principal basis of both technologies was already known by the end of the 20thcentury. Some companies implemented horizontal drilling in 2004, but the shale oil revolution could not have happened until recently, as, historically, the implementation of these technologies had been commercially unaffordable. Moreover, the effectiveness of fracking has been growing with the development of certain chemicals (including acids for carbonate reservoirs) and propping agents—until the 1970s, sand, steel, and other materials were used to prevent the fractures from closing. Later, polymers changed the market and, today, propping agents are preferable. After the success of shale resource extraction in the USA, many countries aspire to repeat the success of the American shale story. Still, it seems that the majority will either give up trying, or the

achieved results will be far more humble than was expected. There are a number of reasons for this, namely financial, socio-political, and ecological. The global shale revolution is on hold. However, the tendencies clearly show that the process is not stagnating; the market conjuncture and the reluctance of financial institutions to invest in shale oil and gas exploration and production lead to the slow pace in implementation of this technology.

Let us, briefly, describe what shale oil extraction is (shale gas is extracted in a similar way). After exploring a territory and assuming that there are commercially sustainable reserves in the oil-field, the company starts drilling. After reaching the production layer, the well turns from vertical to horizontal (horizontal is considered to have an angle more than 85 degrees to the vertical part, but it is essential that it goes through the layer as long as possible—the longest step-out of a well is 14,129 m [2], but the average length of a horizontal well is 600–900 m [3]). Thereafter, fracking liquid is pumped, under high pressure, into the well. This liquid consists of water and propping agents (99%, on average) and chemicals (1%), or acidic liquids that dissolve the carbonate reservoirs. The fracking liquid makes micro-cracks in the layer and, afterwards, is extracted from the well with the oil. Then, the fracking liquid is separated from the oil and transferred to isolated reservoirs, as it can no longer to be used. The main accomplishments achieved by the industry with the implementation of the fracking technology, as well as the possible obstacles for its development, are explained by the fracking process itself and its limitations. In this study, we describe some of them.

The research is aimed at figuring out whether the shale revolution is a global trend, or if it is just a matter of industrial development in a couple of countries. The main issue we see in the previous work on the theme is a lack of comprehensive analysis: most of the researchers have concentrated on the analysis of concrete countries and economies, without comparing them. In addition, we have not encountered any forecasts for the industry on a global scale. Comparative analysis of the current trends of shale development in the selected countries (those that seem to be the most prospective for shale hydrocarbon extraction) is one of the main instruments used herein to answer the question of whether the shale revolution will become global. The practical significance of the article lies in the sphere of recommendations given for the development of the shale industry for each country. All of the recommended measures contribute to the global development of shale oil and gas and, hence, to the proliferation of the shale revolution. Hence, another aim of the article is to discern the scenarios of shale industry development and highlight the most effective path for further industry development. This article contributes to forming a wide approach and vision of the development of the global shale industry and gives a comprehensive overview of the politics regarding shale industry development in key countries, and helps to develop long-term strategies for the named countries.

2. Literature Review and Methods

The technological side of the shale revolution is described in a vast number of works (e.g., [4]), but that aspect of the topic is not among the main interests of the authors. The financial impact of the shale revolution is thoroughly researched in References [5,6], but the authors concentrated on the financial consequences for the U.S. economy only. They assumed that this shale revolution played a vast role in boosting the American economy and cutting down the budget deficit. They described the massive price shifts that, according to their opinion, yet await the market. Still, the authors paid less attention to the social aspects of shale revolution. The assessment of the effects of shale revolution on oil prices and financial markets was presented in Reference [7]. It repeated the key ideas of the positive effect of the shale revolution on the national economy, due to the factors of a more balanced current account, industrial development, and so on. In addition, a review of the global oil and gas market was provided. Still, the ecological, social, and political aspects were not covered.

The research of market conjuncture changes provoked by the shale revolution is a significant part of energy politics all over the world. The authors prefer European Central Bank research, IEEFA papers, and International Energy Agency outlooks [8]. These sources provide comprehensive data and their analytics involve the best approaches, according to the authors' opinion. Moreover, the sources

mentioned above provide studies that take into account ecological responsibility, and tend to exaggerate less than the EIA (Energy Information Agency). National sources on shale oil and gas statistics and research on the regional and national development of the industry proved to be the main source of statistical data [9–11]. They fill the gaps in the data, gained from the previously mentioned sources, and allow the estimation of the accuracy of the statistics. The environmental aspects of the shale revolution are comprehensively described in References [12,13]. The first source gave a wide number of articles devoted to the consequences of shale oil and gas extraction. It highlighted unobvious risks, such as soil intoxication by dump water (with the consequent transmission of toxins to food and pipe water), alongside the stimulation of diseases in domesticated animals and the harm caused to wildlife. The second source calls for responsibility when implementing fracking technology and gives instances of contemporary ecological politics with respect to fracking. During research of the literature, we have noticed that the quantity and quality of new research (from 2016 onwards) has reduced dramatically (Figure 1).

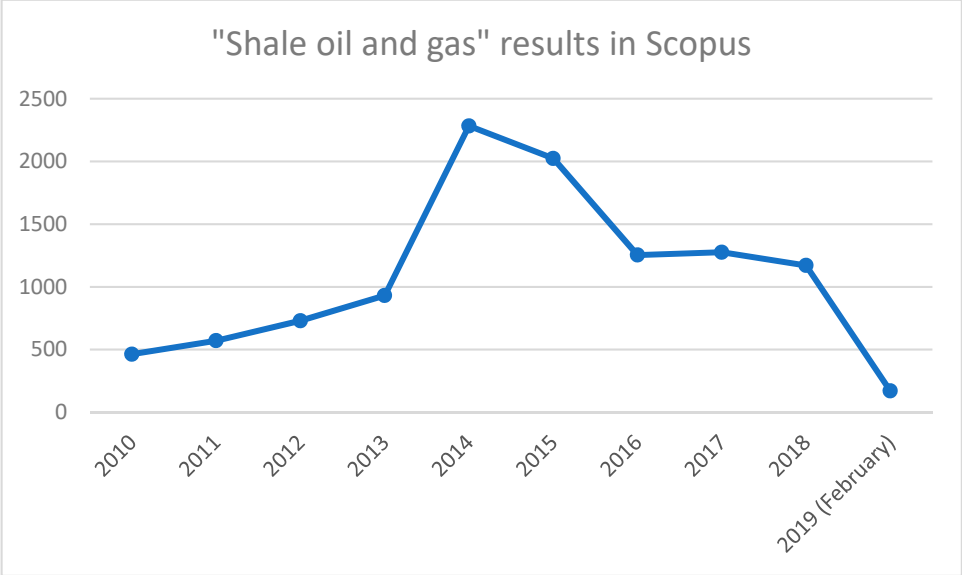

Figure 1. Search results by keywords. Source: Compiled by the authors using the Scopus search engine.

Taking this fact into account, we decided to give a wide overview of the shale industry in the world and were forced to use mostly informational, not analytical, sources. Hence, this article fills the gap in the statistical and analytical research of the industry and covers the last few years of historical data.

Comparison of the economic environment is conducted by comparing two factors: foreign direct investment in the oil industry and market depth. Due to the scarcity of statistics on shale oil and gas extraction and exports (except for the American ones), we offer an approach based on the empirical comparison of shale oil and gas reserves and factual overall crude oil reserves, in the countries studied. When conducting the research, we found that the tendencies of the development of the industry are highly dependent on the institutional development of the country researched. We focused on the main spheres that affected the industry the most, which are the financial market conjuncture and the ecological standards. The estimation of both factors allows us to make a forecast for the country.

According to the EIA [14], the shale revolution went global; however, this statement is doubtful. In order to prove or refute it, we will analyze North American countries and then turn to Europe and Asia. We assume that the shale revolution in the USA and Canada provides enough empirical data for the retrospective and institutional analysis of other countries. The methodological approach to the work is presented, as follows:

1. We research the exports of shale oil and gas and give the developmental trends for the chosen countries. Our choice of countries is based on their readiness to conduct changes in their industry and economy, in order to develop shale oil and gas, and on their geographical position.
2. After statistical analysis, we estimate the overall chance of further shale resource extraction growth—taking into account risks, the financial situation, and ecological constraints—forming a general vision of global shale oil and gas market conjuncture.
3. On the basis of the retrieved data, we make forecasts for the future development of the shale oil industry in the studied countries, chosen for having sustainable shale oil and gas resources, and give recommendations on how to reach a better effect, with lower cost.

3. Results

3.1. The American Shale Revolution

The only country where the shale revolution succeeded, with no doubt, is the USA. Being the first country where shale layers and bitumen sands were researched and proved to be capable of oil and gas extraction, it rose above the main oil exporters in the world and began the commercial extraction of tight oil (a wider term for a number of oil reserve types, including shale oil and light shale oil) in the early 2000s. Even when oil prices were high, shale field development was not very profitable, due to the extremely expensive technology. Still, after a while, it became cheaper and more affordable, but massive funding of the industry was still commercially unprofitable. However, oil imports made a huge contribution to the external debt growth of the U.S.; to reduce them, the Government encouraged gas and oil exploration, and so the economic and natural resource regulations in the USA are aimed at the promotion of industrial development [15,16]. In view of this, some experts (mentioned above [15,16]) stated that the shale revolution could have happened nowhere else.

Despite the rapture around shale oil, a number of problems of high importance arose. The first problem is the corresponding environmental issues—it turned out that the residents of shale field provinces suffered from bad water quality, allergic reactions, and (still unproven) higher cancer morbidity. Higher seismic intensity was also intrinsic to the territories of shale oil and gas extraction. All the mentioned problems, as well as public opinion, led to the ban of fracking in several states [17] (this reference is for our further research, for Australia and other countries).

1. The prospects of the American shale revolution, according to EIA [18], are burgeoning; all the forecasts provided in the research demonstrate high growth rates and put shale oil in the center of the American oil and gas industry. Still, it is worth remembering that the rise of shale resource production was only achieved because of the massive financial support and investment; however, the financial flows in the industry are falling worldwide [19].

Providing an analysis of the shale gas industry in the USA, it is necessary to highlight that American shale gas exports to Europe and Japan were intended to give a sustainable preference for U.S. exporters and upstream companies on the global gas market. Table 1 demonstrates the dynamics of American shale exports, compared to the global gas demand. The forecast is based on a simple linear model (See Appendix A for the R code):

$$y = 1837x - 1395 \quad (1)$$

The forecast demonstrates a stable growth, and it allows us to conclude that the USA is cornering a niche in the gas markets in Europe and Asia. At the same time, we should remark that a non-neglectable part of this growth is provided by the political situation revolving around Russian gas exports to Europe (the European authorities, in order to gain energy independence from Russian exports, are diversifying their suppliers—offering the USA a share of the European gas market).

Table 1. American shale gas dynamics.

Year	Shale Gas Exports, Billion Cubic Metres (bcm)	Global Gas Demand, bcm	Percentage of American Exports
2007	36.62	2958.35	1
2008	59.93	3024.19	2
2009	88.08	2948.12	3
2010	151.12	3176.27	5
2011	226.39	3241.41	7
2012	293.71	3318.33	9
2013	323.27	3371.87	10
2014	380.,82	3399.06	11
2015	430.83	3474.57	12
2016	482.35	3564.,81	14
2017	526.44	3670.80	14
2018	584.78		
2018	636.80	Forecast	
2019	688.83		
2020	740.85		

Sources: Compiled by the authors based on References [20,21].

2. It seems that the trends of the shale oil industry are not as halcyon as the EIA supposes. Despite the efforts of the U.S. to turn its oil industry into a shale oil industry, investors are becoming less optimistic. Their main concerns are that the currently-productive oilfields will run out of oil soon (due to the short maximum profitability of shale well cycles and a low return rate [22]). Moreover, the American producers of shale have had zero, or close to zero, profits for the last four years, so the investors began to withdraw their finances from the industry, and it is expected that this trend will continue in the near future. The second concern is that the development of new fields is risky and needs venture capital, and a sustainable number of venture investors have found a new and more profitable industry—deep-water drilling, where operational costs have drastically fallen [23]. The third issue is the public attitude to fracking which has not changed since the first fracking bans in 2014. This makes investing in shale oil even more risky. At the same time, we cannot say that shale oil has a doubtful future in the USA. It is politically and economically profitable for the American economy. It is a logical conclusion, as the shale revolution allows the U.S. economy to have more maneuverability in trade politics; for instance, to cut the costs of the trade war with China for the budget. For now, it looks like America is going to be on the top of the shale revolution wave in the world. However, it is necessary to understand that the future of the American shale industry is not so bright as the EIA pictures it.
3. The American shale industry will continue to grow, but the more the growth, the further the negative consequences for society there will be. The American shale industry desperately needs new technological solutions, in order to get away from the dump water problems. In addition to that, the USA should be prepared for high volatility of oil and gas prices as competitors enter the market.

3.2. Canadian and Mexican Shale Industry

Canada is the next frontier for the shale revolution. After succeeding in the USA, the shale boom began to spread around the world in 2015–16. Canadian oil companies were the first to follow. The assessment of shale resources in Canada demonstrated that the country has a number of rich plays [24]. In addition to that, Canada possesses oil-sand sites and has developed a progressive industry of condensing oil from them. Shale gas followed the trend [25].

The financial conditions in Canada are similar to America. The depth of the financial market is sufficient for massive investment in the shale industry. Moreover, the Canadian shale industry has not suffered from a misallocation of reserves of shale oil and gas yet and can be profitable at West Texas Intermediate (WTI) prices higher than $70 per barrel [26]. The same source pointed out the problems of shale industry development, namely:

- Lack of infrastructure capacity

- High price spreads between WTI and Western Canadian Select (WCS)

We add to this list:

- Oil price volatility caused by the global market supply and demand pursuit, if the conditions of unpredictable supply prevail (sanctions against Iran, feverish dynamics of Chinese imports, emerging new suppliers—China and India)
- Climate dependence on local demand
- Competition with the USA and Mexico for regional markets

1. The oil sands are one of the most important parts of the Canadian oil industry; they represent no less than 60% of Canadian crude oil extraction. This makes Canada a unique competitor to traditional oil exporting countries due to the sustainable growth of tight oil extraction (see Figure 2).

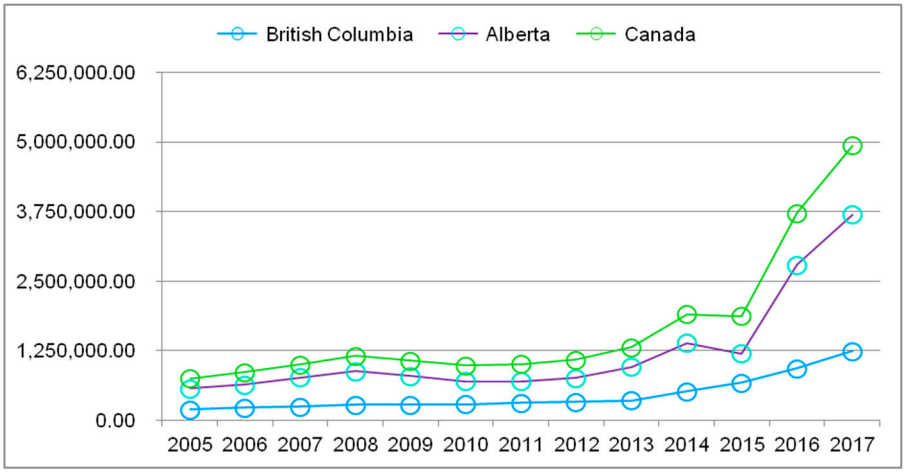

Figure 2. Condensate production in Canada, m^3. Source: Compiled by the authors based on Reference [27].

2 UNCTAD offers a SWOT analysis of the Canadian shale gas industry [28]. Canada does have the opportunities to become a major participant in the global gas market; still, the situation in Canada is highly dependent on the U.S. market and exports. The trends of Canadian shale oil and gas development are positive, but the industry growth rate will be far more moderate than that of America, due to the satellite position of the Canadian shale industry to the American one.

1. Mexico is currently the least developed member country of the North American Free Trade Agreement (NAFTA), and this is obviously one of the reasons why, despite large shale reserves (which are part of Texas plays), the shale industry in the country is still not developed. The potential of the country is vast [29,30], but, as other countries that will follow, does not have a clear strategy of development. The problem lies deeper than a lack of financial resources—depressive tendencies have grasped the most powerful and prosperous industry of the country in the past, the oil and gas industry, not speaking about the Mexican economy. Today, oil production in Mexico is falling at a pace of 3–5% a year, and gas is imported from the USA. The reforms of 2013 have not changed much for the reasons mentioned in Reference [31]; moreover, the power in Mexico is not concentrated in governmental institutions and the country faces a high nepotism rate and, hence, crime.
2. Mexico does not have the problems of a harsh climate, long transportation distances, or a high cost of labor force (as Canada does), but despite its potential for industrial development, Mexico's oil and gas industry is stagnating and cannot attract new investment. The situation will not

change unless American companies have no choice but to enter the Mexican market. The chances of this situation are small but, if the harmfulness of fracking is proved by numerous studies and several catastrophes with a high number of victims in America, fracking bans might be imposed, forcing oil and gas companies to move to Mexican plays.

3. The future of the shale revolution in both Canada and Mexico strongly depends on the U.S. industry trends, but Canada is capable of developing an industry on its own, whereas Mexico is not. According to the current trends described above, we come to the conclusion that both countries need one of the key factors that allow the shale revolution to prosper, and both have the chance to acquire them. Still, their industries bear higher risks and investors will choose their national projects only in the case that no projects in the USA are available. Taking into account the fact that the shale industry in the USA constantly provides new investment opportunities, the chances for attracting new investors to Mexico and Canada are much lower than for the United States.

3.3. The European Shale Industry

The European Union is highly dependent on hydrocarbon imports, especially from its main gas and oil supplier—Russia. The EU conducts an active policy of energy safety, which consists of diversifying imports of hydrocarbons and banning energy monopolies and oligopolies (the Third Energy Package—Directive on gas 2009/73/EC [32]). Additionally, European authorities have actively discussed the question of shale oil and gas production in Europe. The European plays are not as generous as the North American ones and most of them are situated in Poland, Germany, the UK, and France [33]. Germany decided to refuse or, at least, postpone the development of its plays for the reasons of their scarcity and a high population density. Additionally, the technology of fracking is dangerous to the environment, and its implementation in territories close to cities, water reservoirs, and unique natural habitats, bears a lot of risks [34]. A full analysis of the reasons why Europe is not willing to exploit their shale plays is given in Reference [35]. As well as the reasons above, it is possible that the European bowels have been extensively exploited since the beginning of the 19thcentury and, now, their conditions are poor (Poland included). For this reason, the only country in the EU that does have the theoretical ability to develop a shale industry is Poland: it has a fairly big territory, its shale plays are rich (at least compared to other European plays), and the environmental standards in Poland are lower than those in the most developed European states.

1. As the ruckus around the shale revolution began in 2011, Poland started to actively participate in the promotion of this new technology and attracted investment from many transnational giants, such as Chevron [36]. However, the further development of the industry was blocked by a complex of obstacles. Optimism faded away in 2017, when the future of Polish shale industry became clear—there was no future for it [37]. Still, Poland hosts shale gas terminals and U.S. shale gas gets to Europe, for the biggest part, through Poland. While conducting this research, it was noticed that the effect of anticipations on the forecasts in the oil and gas industry is strong. The more economically prospective the play seems to be, the higher the estimations of the potential reserves are. Geological data is exploited to give the projection, but the economic potential corrects the data. One of the illustrations is the situation around the Monterey Shale formation, overestimated by 96% in 2013 [38], but Poland is a far better illustration. According to the most trusted institutes (EIA, National Geological Institute (PIG)), the extractable reserves of the Polish shale resources were significantly bigger in 2010, when the wave of excitement arose, than in 2012 and onwards, when the industry stumbled and faced severe problems, including legal issues (see Figure 3).

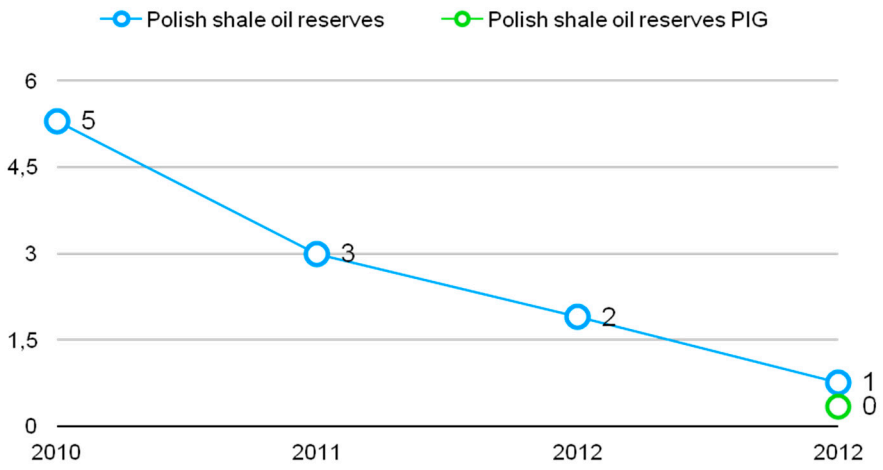

Figure 3. Overestimation tendency, trillion m^3. Source: Compiled by the authors, based on References [39,40].

Great Britain has the finance, technology, and natural resources to develop a shale industry, but the ecological situation on the islands is difficult; thus, Scotland has imposed a fracking ban and English society is actively protesting against shale oil and gas extraction.

Russia has significant shale oil and the biggest potential in gas reserves [41]. The Bazhenov Shale is known to be the biggest shale gas play in the world [42]. Still, as there is an abundance of cheaper sites, the development of shale gas is planned to be postponed until 2025, at least. It is a wise strategic decision in the current situation, as the USA and its European partners are cutting Russian companies off from the technologies necessary for shale development. Moreover, the tendency of gas demand demonstrates that the growth of demand will continue, and the price of this resource is not going to fall in the near future. Considering that the reserves of conventional gas will be falling, the price will tend to rise, and so the exploitation of a difficult site—such as the Bazhenov Shale—will become more and more commercially profitable. In addition, the preservation of the most promising natural resources for future generations makes the country's policy, in the sphere of natural resources, more balanced.

2. The shale revolution in Europe is postponed up to the situation where Russia and the Middle Eastern countries run out of their reserves of conventional hydrocarbons. This situation is complemented by the import of shale gas from the USA, so Europe becomes one of the arenas of competition between shale and conventional gas.
3. As was already mentioned, there will be no massive shale oil and gas extraction in Europe; thus, it will become one of the main importers of energy from other countries. Whether it will be conventional or unconventional oil is a matter of global energy market conjuncture, but European countries will not push the shale industry forward.

3.4. The Asian Shale Revolution

It is vital to consider that Asia is one of the most dynamically developing regions in the world. Hence, its demand for energy resources is constantly growing. The biggest industrial economies of Asia are China and India. Additionally, China has the power and opportunities to conduct an energetic reformation of the economy. The most imported hydrocarbon in China is natural gas and, mainly, the imports come from Russia (Natural gas accounts for 55% of energetic imports in China). The intention to develop a national gas and oil upstream industry is clearly stated by the Chinese officials (for instance, Zou Caineng [43]). In Table 2, we compare the main characteristics of the American market condition at the beginning of the shale revolution and the contemporary Chinese market.

Table 2. The comparison of the main drivers of the American shale revolution and the current situation in China.

The USA	China
High proved reserves [1]	High proved reserves [2]
Many multinational companies (MNCs) and entrepreneurs	Many MNCs and nearly no entrepreneurs
Deep financial market	High governmental financial support
High import of energy resources before shale revolution	High import of energy resources
High development of drilling technology	High potential for technological development [3]
High productiveness rate	High population and labor force resources
Developed system of gas and oil transportation	Fast development of gas and oil transportation system
Low respect for environmental standards	Low environmental standards

[1] 665 trillion cubic feet of shale gas in 2011 [44]; [2] Potentially double that of the U.S. reserves [45]; [3] Zhi et al. [10] proved that China possesses basic technologies and is capable of further development; Sources: Compiled by the authors, based on References [44–49].

In accordance with the mentioned drivers, China has a similar structure in the main shale development factors (resources, finance, determination to develop the industry, and ability for development) but has a different motivation and strategy. In that context, China has the potential to develop unconventional hydrocarbon sites, and has begun the process of supplying its population with the products of shale hydrocarbons [43]. In full compliance with the problems of shale resource development given in Reference [50], China has taken measures to overcome them and their current situation differs from those conditions; however, the success of the Chinese shale revolution is doubtful. The main achievements that PRC reached are located in the Sichuan Basin [51] and were propelled by government-owned companies. Still, as we have mentioned, China has its own path of shale development: in the current economic situation, and in order to follow the «blue sky» strategy, China is forced to develop a shale industry. The most respected experts and agencies expect the extraction of shale gas in China to double by 2020, which will be equal to 17 billion cubic meters [52].

Indian demand for energy resources is significantly lower than that in China, but it is constantly growing [53]. The extent of resources of unconventional hydrocarbons possessed by India is humble, but their development seems to be one of the steps India should take in order to achieve energy independence. It is noticeable that India has not conducted any comprehensive research program, and so the assumptions of the quantity of shale resources in India were made from fragmented data and are unreliable. The Polish scenario seems to be highly probable for the Indian oil and gas industry. Additionally, India does not conduct stimulative policies, as the USA, China, and Australia do; it does not possess the necessary technologies and has a long way to go to make shale development profitable. The main question is whether it is reasonable for India to conduct a large-scale reformation of its economy in the quest for a shale energy surge, with no guarantees and high risks of failure.

1. Australia is another country in the Australasian region that has very interesting prospects for shale oil and gas development. The EIA estimated that the Australian shale gas extractable reserves are around 396 trillion cubic feet—a figure highly distributed in many sources [54]—with the overall reserves accounting for 437 trillion cubic feet, with the main basins lying in the center of the continent. It is a region with low population density, desert landscapes, and low quality and transitional infrastructure capacity. All the mentioned points give Australia several benefits; first of all, in the spheres of ecology and infrastructure development. The Northern Territory implied a long-lasting two-year ban on fracking, lifted in 2018 [55]. It seems that the considerations on budget effects and energy development outweighed the doubtfulness of environmental impacts and, now, shale oil and gas extraction is being actively developed in Australia.
2. Even though Australia has significant reserves of conventional gas and exports it, its oil reserves are relatively low, with a consumption higher than the amount of production [56]. Development of shale oil can prove to be a step forward for the Australian oil market; as the continent is separated from any other country by the ocean, importing oil is an expensive practice.

3. Still, there are several difficulties in developing a shale oil industry in Australia—first and foremost, the infrastructure. In the Northern Territory and Queensland, the shale plays are situated far from the shoreline, where the main cities lie. Therefore, the development of the industry needs an expensive infrastructure. The second problem is water supply. As has been mentioned in the overview of the technology of fracking, it requires a lot of fresh water—a scarce resource in Australia. The last, but not the least, is ecology. Australia is a unique natural region with many endemic species, the protection of which is one of the main goals that the Australian ecological policy pursues. The negative impact of fracking on the environment is underestimated, in our opinion, in order to preserve the unique biocenosis of Australia, shale oil and gas extraction should be banned or only proceeded with the uttermost precision and caution and with respect to the conservation of wild nature. The contemporary technologies of shale play development cannot reach the necessary standards of ecological consciousness, so it is vital to doublecheck the possibility of their implementation in Australia.

4. Discussion

It is clear that the shale oil revolution did not become global, as it was forecasted, in 2012, by the EIA [14]. Still, several countries did manage to reform their oil and gas industries, in such a way that it became profitable to develop unconventional oil and gas. We have ranked the countries by their accomplishments in transformation of their oil and gas industries in Table 3.

Table 3. The shale revolution: success or failure.

Managed to Transform	Did not Manage the Transformation
The USA	Mexico
Canada	India
China	Russia
Australia	Poland
	Other EU economies

Sources: Compiled by the authors.

The analysis of economic factors contributing to the success of the shale revolution leads to the conclusion that there are five critically important factors:

- Resource availability;
- Significant financial investment in the industry;
- High demand for oil or gas on the national market, not matched with the national supply;
- High energy resource prices; and
- A light-minded attitude towards environmental impacts.

We highlight the deep political, economic, and financial effects that the shale revolution has had on the global oil and gas market. First of all, the rising supply of oil and gas on the global market under the conditions of stable demand inevitably leads to falling prices. The economies of the biggest energy consumers are slowing down, and the main exporters of energy resources (OPEC+ countries) are cutting down oil production, in order to preserve prices. Iran, before the USA implemented sanctions against it, had scaled up its energy exports [57]. Asian countries are striving to cut imports of hydrocarbons by starting to develop national plays. All in all, these trends lead to the conclusion that the main participants in the oil and gas market are having bad times.

Along with their difficulties, the USA is building on its shale oil and gas exports and trying to gain supremacy on the market. When speaking about the U.S. exports, we mean both exports from the USA and emerging exports from Canada. The only way for the U.S. shale industry to continue to export is to establish dominance over the European market and to find economies that do not have the ability to extract shale oil and gas (e.g., the South African Republic, India, Japan, and island states in

the Pacific which do not have high demand in absolute values due to their size and population). It is remarkable that the USA has no interest in the development of the shale oil and gas industry in Mexico. Furthermore, falling Mexican oil and gas production is profitable for the U.S. companies that find a close and tariff-free market for their products. Countries from Central Asia and less-developed African states are a bad choice for expansion, as the former are supplied by cheaper (in terms of production and logistics to Central Asia) natural gas from Russia, while the latter do not need energy resources, due to their low level of development and the availability of cheaper natural resources from the Persian Gulf.

Analyzing the American energy diplomacy, compared with the U.S. foreign policy, the authors have come to the conclusion that the USA has a long-lasting plan for energy market conquest. The plan involves measures that will allow the USA to export hydrocarbons to the struggling regions mentioned above. The first step was creating an effective shale oil and gas industry. Then, the destabilization of situations in the Middle East and Northern Africa—we do not push forward the idea that the current anti-democratic and anti-social regimes and tensions in the regions were created by the pro-American forces, but it is a highly probable scenario. In this case, the USA achieved at least two goals in economic diplomacy: firstly, it boosted the sales of its military production and, secondly, it exterminated stable oil and gas supplies in several countries, which were formerly the key exporters of these resources. The decision of the Trump administration to abandon the Iran Nuclear Agreement and impose sanctions against another oil exporter fits into this strategy perfectly. Anti-Russian sanctions pursued a different goal, but they cast into doubt the reliability of Russia as a trade partner (it seemed to be the first step in cutting down the exports of energy resources from the Russian Federation in the near future). These measures were intended to weaken the key participants of the energy market and to allow the USA to find a niche for its shale exports.

At the same time, we have noticed that the EIA often gives a higher estimation of shale oil and gas reserves for countries which express their intentions for the development of shale oil and gas. One of the examples was given above—the highest estimation of Polish shale oil reserves was given by the EIA. At the same time, we cannot forget the story of the Monterey Formation in California, one of the biggest mistakes of the EIA [38]. Several other sources prove that the EIA tends to overestimate resources, and no serious mistakes underestimating the reserves were not made [58–60]. These sources, discussing the trends of reserve estimation, are a base for further supposition that the EIA intently stimulates investments in shale industry. The shale industry is buttressed by a bundle of technological solutions, patented and developed mostly by American companies. It looks like these mistakes are made intently, in order to stimulate the demand for shale exploration and development of equipment.

The European vector of the shale revolution comprises the quest for energy independency and ecological consciousness. The second part is more important for European countries, due to their historical heritage, mighty negative public opinion, and high population density. Europe will not be an energy supplier, neither will it have self-sufficient energetic balance. Still, it plays an important role in the history of the shale revolution, as, due to its climate and industrial development, it consumes a high amount of energy. At the same time, Europe has significant financial resources and a developed infrastructure, which makes it an ideal market for energy resources—the three main energy partners of Europe are, traditionally, Russia and the Persian Gulf countries that suffer from the negative effects described above, and a newcomer: the USA. We should remark that, despite the rise of American energy exports to the EU, the main partners remain the same—Russia and the Persian Gulf countries cannot afford to let the U.S. oil and gas dominate Europe, and will be forced to offer preferential prices to European countries after 2020, when the volume of long-term gas contracts will fall [61]. The other main exporters of gas and oil to Europe have their disadvantages for the European market. American companies, due to the mentioned issues, have comparative advantages and seek to ripen them [62].

The American strategy is complex, and it seems to be effective. We recommend they stick to it, but we express our deep concerns about the future of the American environment and living conditions. The global goals America pursues cannot be achieved without costs, but the ecological devastation trends are worrying.

In our opinion, Europe gains a number of advantages from the shale revolution in the USA, because it gets a choice of partners and better prices. The development of shale oil and gas in Europe does not have bright future and, if it becomes profitable or break-even, the scale will not be significant. We recommend using the financial resources freed by better prices on oil and gas, achieved because of competing exporters, to foster alternative energy in such countries as Germany, Sweden, Norway, Denmark, Finland, Italy, and France. These countries develop alternative energy in their own way, and it has proved to be effective. This will allow them to cut down their expenditures on energy imports even further and preserve nature.

Asia is opening many new horizons for the shale revolution. First of all, the persistent Chinese search for energy resources may be accomplished with the discovery of national shale oil and gas plays. The increase in demand can be satisfied by the growth of national production. Additionally, China has realized the negative effects of the coal economy, and so clean energy (or, at least, cleaner than coal) is needed. Further, China is trying to fight the American trade war, and wants to establish an energy partnership with Japan. PRC is developing the idea of a Belt and Road Initiative, which was recently augmented by the idea of a so-called "community of shared future for mankind". In order to spread its power in Asia under the paradigm of the mentioned projects, China is investing in both energy and infrastructure in the region. These investment projects can be perfectly supplemented by Chinese energy resources exports. The political controversies between China and India force the latter to try to form a counterforce for Chinese expansion in Asia. One of the strategies available for India is to become an energy resource exporter but, as it possesses only shale oil and gas, the only track India can follow is to try and develop a shale industry. Still, because of poor regulation standards, high population density, poor environmental standards, and low reserves, we stick to the opinion that India will not be a serious participant in the Asian shale energy market. Still, it is worth mentioning that India is gaining a role as a main importer of energy resources, and that this trend will continue.

Both China and India need to consider ecological matters; due to high population densities and low environmental standards, the development of shale oil and gas can lead to widespread pollution and harm and may invoke harmful effects in the local population. In order to avoid these risks and build a highly effective industry, these countries need:

- To implement a stricter environmental policy for chosen industries (shale industry included);
- To begin extraction in the least populated areas, to cut down the possible effects of technogeneous accidents that are more probable during the pilot projects;
- Form a list of shale oil and gas plays and point out the order in which they are to be developed; and
- In partnership with Russian and Australian (if it becomes politically possible) companies, develop new technologies that will have smaller negative external effects.

The Australian manner of shale oil and gas development is closer to the American one; moreover, Australia does not compete with the traditional and emerging powers on the global market (for now). There are two scenarios of development for Australia, in our opinion. In the first one, the country provides enough shale oil and gas to cover the internal demand in Australia and the quantity of production is strictly regulated. It is a plausible scenario for the Australian economy, population, and environment, as the balance will be kept between the economic effects and external effects for nature and the local population. Moreover, as we have already mentioned, the wildlife will be affected more significantly than people, due to the low population density in the region. At the same time, thinking ahead, water will be the biggest problem for Australia, both in the stages of providing it for fracking and for toxic tailing utilization. The second scenario is more probable than the latter, as it allows mining corporations to accrue profits. It does not offer any quantitative restrictions on production and will result in massive fracking efforts in Australia.

Traditional oil and gas exporting countries have a skeptical attitude towards unconventional oil. OPEC does not want to develop unconventional oil sites, until the conventional ones are totally worked out. Russia has begun to develop technologies and test them, but they are far from the commercial

exploitation of shale oil and gas. These countries tend to develop deep-water drilling and other, cheaper technologies, because of their competitive advantages. Israel, alongside with the mentioned countries, prefers to avoid using shale technologies, especially after the exploration of the Leviathan gas field [63]. For these countries, we recommend conducting a comprehensive geological research of their territories and developing shale oil and gas extraction technologies, in accordance with a plan that will allow them to produce the same quantity of oil and gas as they do now, by the time when the conventional resources become drafted.

On a global scale, the two centers of emerging energy force are the same as in an economic context; the USA and its allies and Asia, in general. They form a massive competition for the traditional participants and compete with one another.

Hereafter, we offer three main scenarios for the development of the shale industry. The criteria for these scenarios are: (1) the pace of the development of shale hydrocarbon extraction; (2) the geographical position of the countries where the shale oil revolution will succeed; and (3) the shale technology development.

- High and fast development of shale industries in the countries where the shale revolution succeeded; other countries do not implement these technologies in oil and gas extraction. The global energy balance reformats and shifts to the USA and China; traditional exporters face new competitors and act in accordance with the market laws—they cut down the prices. The supply from shale oil and gas exporters shrinks, the prices grow, and so on until the new balance is found. This balance will tend to give more preferences to the countries which export unconventional oil. The oil market will be divided into two sectors: conventional and unconventional oil and gas, where oil and gas prices will be different. The market of long-term gas contracts will face decline. The process will be painful for all the participants, except for the consumers, who will enjoy low prices. This scenario is possible if new, more ecological extraction technologies are developed.
- The development of the shale industry leads to harsh competition with the traditional exporters, forcing the newcomers to leave the market or fencing in a statistically neglectable niche on the global market. Still, the traditional exporters will lose Asian and American markets, which will lead to a sharp drop in prices. Russia, Venezuela, and other countries with high oil and gas production costs will lose their positions on the global market and will have to transform their industries in order to cut costs or enhance productivity. The newcomers will probably not conquer new markets, where the traditional exporters will lose their positions, as the supply of unconventional oil and gas to these markets is problematic and expensive. Additionally, countries where the shale revolution succeeded will have to endure low prices, which will have a far more devastating effect on unconventional oil extraction than on conventional oil extraction.
- The shale industry will be proved to be harmful for nature and its effects will be too negative to bear, so the development of shale plays will decline. The market will face a moderate growth of prices, and its conjuncture will resemble that of the early 2000s.

5. Conclusions

The global energy landscape is changing rapidly. The main driver of these changes is the shale revolution which has taken place in a small number of countries, yet still has global consequences. The future of the global energy market, in the short run, remains the same but, in the long run, new participants will emerge and fight their way to the top of the hydrocarbon-exporting countries. Shale oil and gas account for up to 80% of global reserves [64], so energy politics, along with the development of the technology, is destined to change, but it will not happen in the near future. Until low prices hold, conventional oil and gas will dominate the market. The two centers of the shale revolution are formed: China and the USA. They are likely to become competitors in the near future (by 2020, China will enhance its production of shale oil and gas and export it to other Asian countries). In the context of the trade war between China and the USA, Russia (with its large reserves of shale

oil and gas) becomes an important participant in the forming triangle. Still, the shale revolution is a supplementary effect of global power shifts, yet has its own specific aspects.

The future of shale oil and gas is still doubtful. In order to succeed, the shale revolution needs several factors (we highlight five main factors). The scenarios offered above are all probable, but we tend to stick to the first scenario, as it seems the most reasonable and most trends, discussed above, point towards it. Additionally, financial conditions and the economic development of the mentioned countries are better than in the ones where the effects of shale revolution are lower. The horizon of the forecasting begins in 2020, while (in our opinion), by 2040, the energy market will be reformed by the use of new fuels, and oil and gas will be used much less than currently; thus, the impact of the shale revolution will last for 20 years, and the new balance will be totally formed by 2025.

The countries that did not manage to transform their industry will play a less significant role in the oil and gas markets, regardless of their position on the market today. The key participants of the shale hydrocarbon market will have to develop new technologies, in order not to inflate the growing negative external effects of the industry.

The comparison of the external institutional effects on shale hydrocarbon extraction in the chosen regions demonstrates that, in every case, the main question of whether to develop the shale oil and gas industry or not depends highly on the public attitude towards nature preservation and population density. The countries where shale resources are actively developed either do not have a strong "green" lobby, or the lobby of multinational companies is extremely strong. This results in the conclusion that the institutional effects on shale hydrocarbon extraction are negative. The economic results are, at the same time, moderately positive. As was proved above, countries which are extensively developing shale resources are becoming new exporters of hydrocarbons, which contributes to their prosperity. At this point, an extremely important question arises—what prevails for the countries named, budget profits or social responsibility? For now, social responsibility prevails (the countries where shale revolution did not succeed are more numerous). However, if the dynamics of the development of the shale industry remain the same, we will face a number of negative external institutional effects; for instance, an extreme widening of the influence of multinational companies on the everyday life of citizens and the exploitation of natural resources. The positive economic effects, which include higher tax revenues, better living standards of the citizens, living near to the plays, and so on, can exceed the negative consequences described above, but, for now, discovering whether the positive or negative aspects of shale development are more pronounced is a subject of discussion and a matter of personal opinion. Research of the mentioned countries demonstrates that, for now, the economic effects in the countries where the shale revolution has succeeded are significantly bigger, but in some of the countries where it did not manage to succeed, there is a desperate search for energy resources and the majority of (if not all) the other factors for successful shale development are present. We conclude that the shale industry is under high pressure from the conventional oil industry and the "green" lobby, and we expect a massive face-off of these parties in the near future.

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Appendix A

R code for Equation (1)

```
y<-c (1293, 2116, 3110, 5336, 7994, 10371, 11415, 13447, 15213, 17032, 18589)
t<-c (1,2,3,4,5,6,7,8,9,10,11)
mod<-lm (y~t)
mod
summary(mod)
```

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