THE US SHALE GAS REVOLUTION AND ITS ECONOMIC IMPACTS IN THE NON-US SETTING: A RUSSIAN PERSPECTIVE

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* The chapter is based, inter alia, on the following publications and presentations of this author on the shale gas-related issues:

- *Publications:* (1) Сланцевый газ: не конкурент, но стимулятор реформы экспортного ценообразования Газпрома (комментарий к статье К.Барыщ "Сланцевый газ и энергобезопасность Евросоюза"). – *"Нефтегазовая Вертикаль"*, 2010 г., № 18, с. 28–29; (2) The economic implications for Europe of the shale gas revolution. – *'Europe's World'*, 13 January 2011, www.europesworld.org/NewEnglish/Home_old/CommunityPosts/tabid/809/PostID/2188/TheeconomicimplicationsforEuropeoftheshalegasrevolution.aspx; (3) "Эффекты домино" американской сланцевой революции. – *"Вестник аналитики"*, 2014, № 1(55), с. 87–94; (4) Американская сланцевая революция: последствия неотвратимы. – *"ЭКО"*, 2014, №5, с. 111–126;
- *Presentations:* (1) 'Shale gas: Economic and Geopolitical Implications for Russia'. – Presentation at the *Transatlantic Energy Governance Dialogue* Conference 'Shale Gas. A game changer for European energy security?', Central European University, Budapest, Hungary, 12–13 May 2011; (2) 'Shale gas as 'game changer' for the European energy market? A perspective from exporter's angle (Economic and Geopolitical Implications for Russia)'. – Keynote speaker's presentation at the Conference 'Unconventional Gas Market Scenarios: Economics, Supply & Pricing Strategies for Upstream & Downstream Operators', Ramada Hotel Alexanderplatz, Berlin, Germany, 21–22 May 2012; (3) "О возможных последствиях превращения США в экспортера СПГ (приглашение к дискуссии)". – Московский международный энергетический форум "ТЭК России в XXI веке" (ММЭФ-2013), Круглый стол/открытое заседание Программного комитета ММЭФ-2013 "Энергетическая Стратегия" России: догма или изменяющийся взгляд на перспективу?", Москва, 07 февраля 2013 г; (4) ' 'Domino Effects' of US Shale Gas Revolution: International Consequences in Institutional Sphere'. – Presentation at Forum 1: 'Keynote Forum – Decoding Global and Chinese Trend on Emerging Industries', BIT's 1st Frontier Industrial Forum-2013, Qingdao, China, 24–25 October 2013.

Active discussion regarding the nature and possible consequences of the US 'shale revolution' is still under way worldwide, including in Russia. Some scholars like this author are quite confident that such revolution took place.[1] Others, without casting any doubt on the American phenomenon of shale gas, do not believe in the global nature or global consequences of shale gas, citing disappointing results of shale exploration outside US.[2] Others call the whole US shale gas phenomenon a 'would-be shale revolution initiated by the USA', and go even further to say that US shale gas success was a special operation of the CIA, with shale development 'key to repartition of national and global commodity, financial and political markets'.[3]

The peak of public debate in Russia on shale gas developments took place in spring 2013, when the CEO of Gazprom Alexei Miller stated on 30 March on the primetime television programme *Saturday News* ("Вести в субботу") that US shale gas production is not profitable, and this 'bubble' will burst soon.[4] Earlier he stated that his company is not considering shale gas production in Russia and would like to concentrate on shale oil instead.[5] Immediately the Vice President of Rosneft (and active television commentator) Mikhail Leontiev argued, on the contrary, that Russia and Gazprom have dozed away the shale revolution,[6]

1 Н. Иванов. Сланцевая Америка: энергетическая политика США и освоение нетрадиционных нефтегазовых ресурсов. – М.:, Магистр, 2014, 304 с. (N. Ivanov, *Shale America: US Energy Policy and Non-Conventional Oil & Gas Resources Development*, Master, Moscow, 2014, 304 p.).

2 С. Мельникова. "Великая сланцевая революция?" Лекторий СВОП, 28.2.2014 (S. Melnikova, 'Great shale revolution?' – 'Lyceum of the Council of Foreign and Defence Policy', 28.2.2014) <https://www.youtube.com/watch?v=virrnojnP6g&spfreload=10>.

3 В.А. Цветков, Е.Л. Логинов. "Цели и организационная модель манипулятивного обрушения цен на нефть – 2014 Аналитический доклад" М.: ЦЭМИ РАН / ИПР РАН, 2015, с.9–10 (V. Tsvetkov and E. Loginov, 'The aims and organizational model of manipulated rockfall of oil prices – 2014', Analytical Report, Central Economic & Mathematic Institute/Institute of Market Problems, both of Russian Academy of Sciences, Moscow, 2015, pp. 9–10). According to them, the 'US shale project was organized by former CIA Director John Mark Deutch who has chaired the US DOE Sub-Committee on shale gas'.

4 "'Газпром': сланцевый 'пузырь' США скоро лопнет ('Gazprom: US shale "bubble" will blow out soon'), 30.3.2013 <www.interfax.ru/business/298546>; "Миллер: сланцевый "пузырь" США скоро лопнет" ('Miller: US shale "bubble" will blow out soon'), "Газета.Ru", 31.3.2013 <www.gazeta.ru/business/news/2013/03/31/n_2826333.shtml>; "Миллер: Добыча сланцевого газа в США нерентабельна, и этот 'мыльный пузырь' скоро лопнет" ('Miller: shale gas production in USA is non-profitble and this "bubble" will soon blow out'), 1.4.2013 <www.ng.ru/economics/2013–04–01/4_industry.html>; etc.

5 'Глава "Газпрома" Миллер назвал "неактуальной" добычу в России сланцевого газа' ('Gazprom head A. Miller called shale gas production in Russia "not actual"'), 29.10.2012 <www.newsru.com/finance/29oct2012/slanetc.html>.

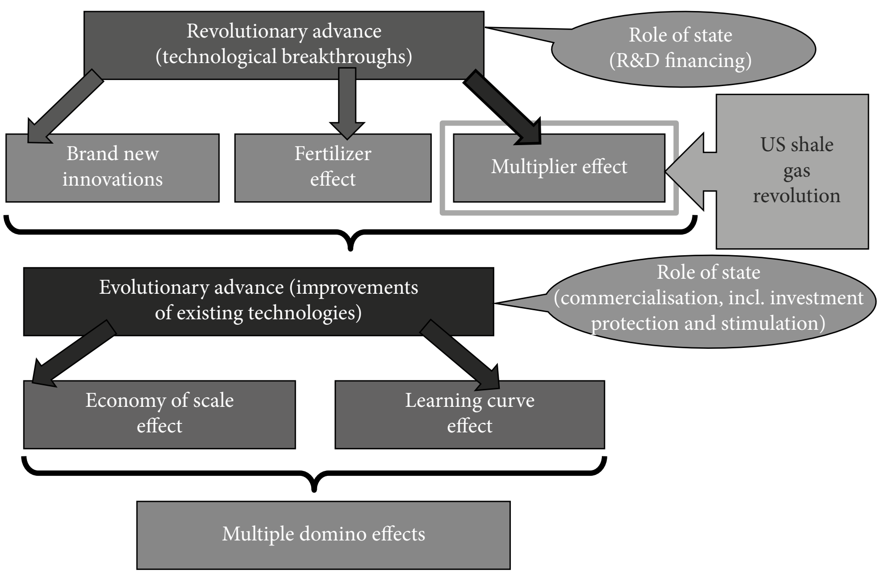
6 М. Леонтьев. "Россия проспала "сланцевую революцию"" (M. Leontiev, 'Russia has overslept "shale revolution"') <https://www.youtube.com/watch?v=9gt--k18HSk>.

and that Russian companies should immediately rush out in pursuit of shale resources, in order to prevent Russia lagging behind other countries in pursuit of the shale gas phenomenon. This raises a number of questions regarding the nature of shale gas development in general, and the US shale gas phenomenon specifically.

1. SHALE DEVELOPMENT AND TECHNOLOGICAL ADVANCES

Shale development is not entirely new, and has been used in a number of countries, including Russia. The journal *Oil Industry* ("Нефтяное хозяйство"), the oldest industrial publication of the USSR and modern Russia, and well known within the oil community, was first published in the 1920s under the title *Oil and Shale Industry*. In the Soviet era, shale fields were developed in Estonia and gave their name to the city of Slantsy (Russian for 'shale') in the nearby Leningradsky region. At that time, it was not shale gas development in the modern sense, but rather shale rock, which was used as solid fuel in nearby power station for electricity generation.

Figure 4.1. Two types of technological advance and the US shale gas revolution



Source: A. Konopyanik. '"Domino Effects" of US Shale Gas Revolution: International Consequences in Institutional Sphere', presentation at Forum 1: 'Keynote Forum – Decoding Global and Chinese Trend on Emerging Industries', BIT's 1st Frontier Industrial Forum, 2013, Qingdao, China, 24–25 October 2013.

Shale development in the twentieth century was put on the back burner as cheaper hydrocarbon resources were readily available and therefore 'traditional' or 'conventional' from a commercial viewpoint. Shale resources were considered 'unconventional' from a commercial development perspective, and their transition to being commercially 'conventional' became possible after emergence of several breakthrough technologies. There are generally two types of technological advances: revolutionary and evolutionary (see figure 4.1 below). It is the revolutionary nature of technological advances that forms the foundation of the American shale revolution, making it possible to consider it a genuine revolution both in its immediate and indirect consequences for both the national and global energy industry and economy.[7]

Revolutionary technological advances are the breakthrough technologies, fundamentally new developments, and innovation bringing about dramatic changes in our life conditions, opening up new horizons, creating domino effects in related industries and causing the emergence of new industries and businesses. In contrast to this are *evolutionary* advances through cost-cutting, based on technological improvements achieved by accumulation of experience of their implementation in the given technologies initiated by technological breakthroughs (the so-called 'learning curve' as illustrated in figure 4.1). Some of the most conspicuous achievements through revolutionary technological advances are personal computers and the Internet, and previously nuclear energy, space development (the jet engine), and the automobile (internal combustion engine). Prior to these advances, revolutionary developments include the locomotive (steam engine), windmills and watermills. All of these brought about fundamental changes in lifestyle and had a domino effect similar in scale to that analysed below with respect to the consequences of the US shale revolution.

Implementation of revolutionary technological advances in separate industries may be based on innovative developments originally designed for application in any given industry, or draw on an adaptive technology transfer from one industry to another. A good example is that of seismic methods used in the exploration of natural resources; these were developed in the early twentieth century for use in artillery, but today are mainly applied in oil prospecting. Another example is that of jet turbines (which are small in size and powerful) which were adapted and used in compressor stations for pipelines and on

7 This is why, for instance, Vagit Alekperov, CEO of Lukoil, prefers/proposes not to use the term 'US shale revolution' but instead 'US technological revolution' (Вагит Алекперов в интервью RT: США не совершали "сланцевую революцию" ('Vagit Alekperov in interview to RT: USA has not accomplished "shale revolution"'), 25.3.2013 <http://topwar.ru/25882-vagit-alekperov-v-intervyu-rt-ssha-ne-sovershali-slancevuyu-revolyuciyu.html>). But this author will continue to use the term 'US shale gas revolution' due to its specific character related not only to US technological advances but to broader characteristics of the US economy, including in its comparison with other countries, that made US shale revolution possible in this particular country.

offshore platforms for power generation. This type of technology transfer is called the 'fertilizer (nutrition) effect' (see figure 4.1).

However, the American shale revolution had a different trajectory. Rather than innovative development, it was the result of a multiplier effect (see figure 4.1) achieved by the amalgamation of several individual (separate) revolutionary technological advances into a single commercialised system, putting together in a single technological set a number of breakthrough technologies that had been known earlier but never before applied in combination. These technologies that were combined included developments in seismology (transition from 2D to 3D seismic surveys), drilling (implementation of controlled directional and/or horizontal wells along with the vertical/sidetrack wells), and stimulation methods (transition from single to multiple hydraulic fractures). As a result, multiple hydraulic fractures (hydrofracs) on horizontal and controlled directional wells in the framework of 3D field surveys (including 3D online surveys in the process of controlled directional drilling) have become the technological basis for the American shale revolution, bringing about a radical reduction in the technical costs of shale hydrocarbons development.

However, this technological revolution was insufficient for the American shale revolution to take place.[8] Other factors came into play, including economic (tax and investment incentives), legal (legal model for subsoil use), financial (cheap and easily available loans, diversified instruments for risk hedging/mitigation), institutional (a variety of small and medium-sized companies operating in a highly competitive environment fostering their competitiveness), and infrastructure development (diversified and with high density transportation network and of other utilities available for high mobility of all operations). Thus the US economic model in its entirety facilitated the shale revolution, as it enabled the rapid implementation of shale projects with concurrent reduction of their financial and transaction costs, not in spite of, but rather owing to, common interests of all participants in the value-added chain in the shale industry. Added to this was a favourable combination of market conditions (growth of oil prices and natural gas quotes de facto tied to them in the 2000s). Finally, and probably most important, was the role of personality – the outstanding tenacity demonstrated by the shale gas pioneer George Mitchell in the pilot implementation of multiple hydrofracs on horizontal wells, thereby bringing this technology to commercialisation.[9]

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8 This is why I would like, contrary to V. Alekperov's proposal (*supra* n. 7), to continue calling this revolution the 'US shale gas revolution', not just a technological one.

9 In this author's view, the role of George Mitchell in modern energy (in practical implementation of energy innovations which generated revolutionary and irreversible changes not only in US national energy, but in the global economy) is so great that he could have been short-listed for the annual 'Global Energy Prize', which was established by a group of Russian energy companies a few years ago as (to some extent) an analogue to the Nobel Prize. This author was a member of International Expert Committee of the Global Energy Prize in 2012–

Hence, the combination of technological achievements (3D seismic surveys, plus horizontal and controlled-directional drilling, plus multiple fracking) has led to a decrease in technical costs. Concurrently, there have been growing oil and gas prices in the 2000s, improved pre-tax shale economics (increased before-tax profit of shale gas producing companies), and favourable fiscal and investment stimuli (non-confiscatory mineral resource rent sharing, and tax concessions to shale gas producers as risk rewards to these companies improved after-tax shale economics). As a result, the increased technical capability, economic viability and institutional simplicity have combined to facilitate the development of a new cluster of energy resources, previously widely known but commercially unprofitable. The result of the coalescence of such factors has meant that the price of oil and gas has risen, exploration and production costs have dropped (the so-called 'cost-price scissors' have opened), and margins have increased, bringing the American shale revolution into being. Such a revolution, like all revolutions, triggered a chain reaction of domino effects, global in their consequences.

2. WHY IN THE US AND NOT ELSEWHERE?

One could point to dozens of reasons as to why the first shale revolution happened in the US when it did.[10] It is for these same reasons that the shale revolution can hardly be expected to reoccur anywhere else in the world, at least at the same scale and pace as in the US. What follows is an analysis of the reasons why the shale gas revolution did occur in the US and did not and would not occur in the rest of the world.

First,[11] although the general data confirming a rich resource base of both dry and wet (i.e. with high liquid contents) gas can now be considered already as well proved, particular figures of shale gas resource base are not yet stable and present a broad range of fluctuations of resource estimates, depending on the data source.[12] Nevertheless, based on various sources, the US has

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2015 and thus was not allowed to nominate candidates during this period. This is why, and since Mr Mitchell passed away in 2013 (the premium is not awarded posthumously), it was not possible float this suggestion, voiced in 2014, because of procedural considerations.

10 A good and detailed analysis of the changes in US energy resulting from the 'shale revolution' is presented in the book Н. Иванов. Сланцевая Америка: энергетическая политика США и освоение нетрадиционных нефтегазовых ресурсов. – М.:, Магистр, 2014, 304 с. (N. Ivanov, *Shale America: US Energy Policy and Non-Conventional Oil & Gas Resources Development*, Master, Moscow, 2014, 304 p.

11 Although this does not appear to be the main driving force behind the American phenomenon, but rather the necessary 'starting point' for any unconventional energy resource development to be considered as a potential conventional one.

12 This presents, from my view, the phenomenon described by the so-called and well-known 'Arps diagramme', explaining broad range of reserves assessment fluctuations (range of

been consistently placed in the top five countries with the largest technically recoverable resources of shale gas, although according to different sources they hold different positions within this top five. Moreover, sometimes the figures presented in publications differ, even though they have come from the same source, such as the US Department of Energy's Energy Information Administration (DOE EIA):

- according to *MIT Technology Review*, citing the EIA, the US and China hold equal first place in the top five shale gas resources countries, followed by Argentina, Algeria, Canada, Mexico, etc. (see figure 4.2). However, according to another MIT publication, China outstrips the US in production by 1.5 times;[13]
- utilising EIA data, one *Financial Times* shale gas article[14] placed the US as the lowest of the top five countries in technically recoverable shale gas resources. The rankings according to the *Financial Times* included China (2.6 times the US resources), Argentina (1.6 times the US resources), Mexico (1.4 times US resources), and South Africa (by fractions of 1%). In the article two other countries were placed close to the US levels – Australia and Canada each possessing about 80% of the US shale gas resources (see figure 4.3);
- according to another *Financial Times* publication, with reference to the EIA and CIA World Factbook,[15] China outstrips the US in the volumes of technically recoverable shale gas resources by 1.5 times; all other countries are below the US in this rank: Argentina (90% of US), Algeria (80% of US), with all other countries placed further below (see figure 4.4).

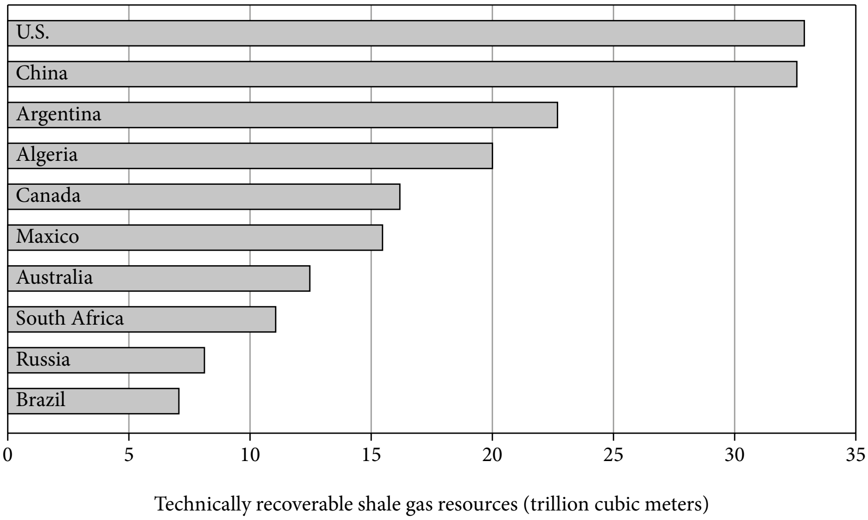
recovery estimates) at initial stages of data collection from comparative to volumetric to performance (see: J.J. Arps,, 'Estimation of primary oil reserves: Transactions AIME' (1956) 207 *Journal of Petroleum Technology* 182–191).

13 'The Future of Natural Gas. An Interdisciplinary MIT Study', 2011, p. 154, Figure 7.3: 'Global Shale Opportunities: Technically Recoverable Shale Reserves and 2009 Consumption'.

14 *Financial Times* shale gas series, 22–25.4.2012.

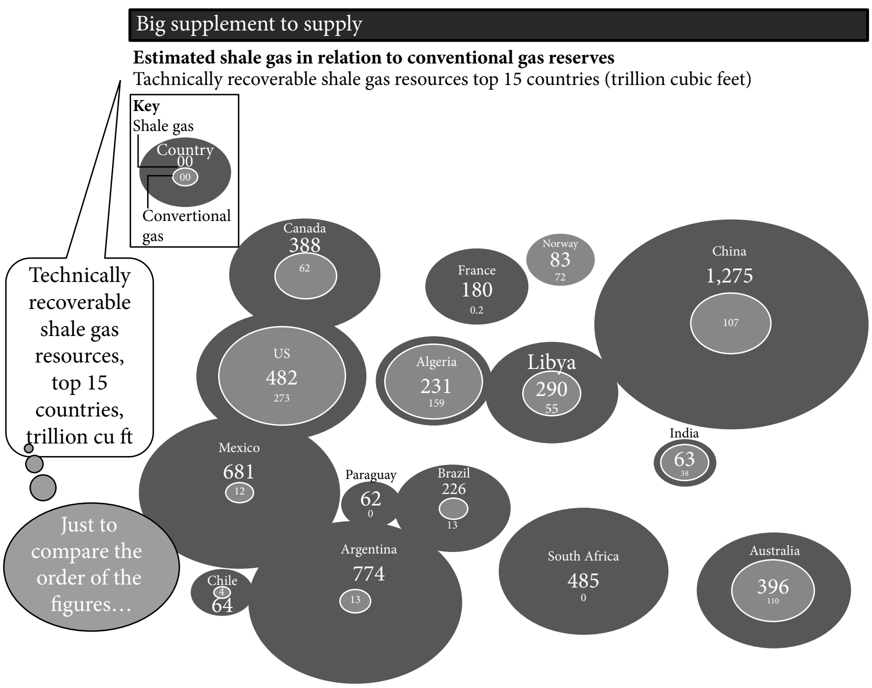
15 *Financial Times*, 9.12.2011.

Figure 4.2. First top-10 states with highest technically recoverable shale gas resources (according to EIA DOE)



Source: http://www.technologyreview.com/news/539366/where-is-the-global-shale-gas-revolution/.

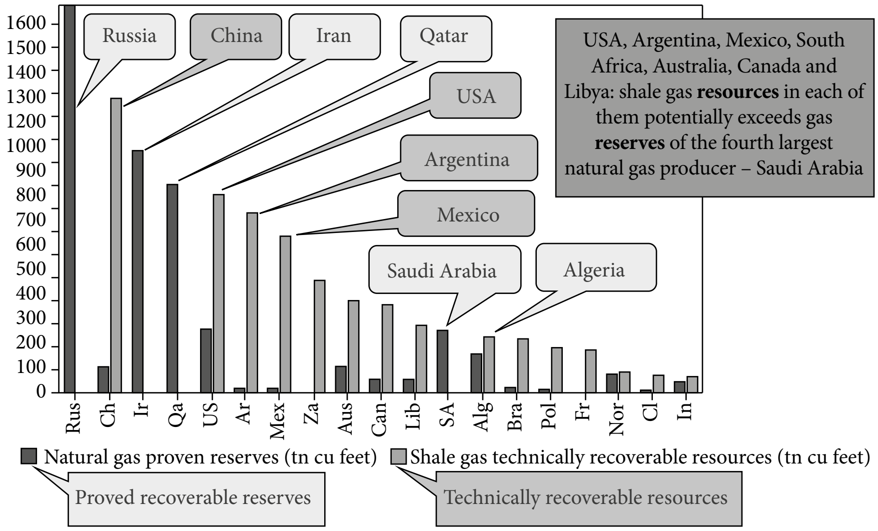
Figure 4.3. Conventional gas reserves vs shale gas *resources*



China, Argentina, Mexico, South Africa, Canada, Australia, etc. – New players at the world gas map? When & at what cost?
Source: based on *Financial Times* shale gas series, 22–25 April 2012.

PROEF 2

Figure 4.4. 'Volume of shale gas resources, potentially, is sufficient to radically change gas market. If you can extract them…' (*Financial Times*)



Source: *Financial Times*, 9.12.2011, with reference to EIA, CIA World Factbook.

All of these other countries, not yet listed as major energy producers, should be as interested as the US in the development of their energy resources, including shale. However, for them (apart from Australia and Canada) development of their own shale gas resources remains a task for the future, while in the US the peak of the shale gas revolution has already been reached (and is being substituted by reaching the peak of the US shale oil revolution). This means that the key factor is not the resources per se, but rather a combination of factors in turning the technically recoverable *resources* into the proven *reserves*, i.e. thus making shale gas development profitable.[16] This combination of factors can be defined as the investment climate and the institutional environment. These two factors in the US are more advantageous than in any other country, demonstrating that it was not the resource base (the estimated resources/reserves) which played a key role in the US shale gas revolution, but rather the investment climate and institutional environment.

16 Or, in other words, bringing them from outside 'Hubbert's curve' to inside (under) this curve, which transfers non-conventional energy resources into conventional ones (see Box 2 and figure 4.16; see also 'Explaining Oil and Gas Pricing Mechanisms: Theoretical and Historic Aspects' (Chapter 2) and Figure 3 (p. 53), in R. Dickel, G. Gunul, T. Gould, J. Jensen, M. Kanai, A. Konoplyanik and Y. Selivanova, *Putting a Price on ENERGY: International Pricing Mechanisms for Oil and Gas,* Energy Charter Secretariat, Brussels, 2007, 236 pp.

Secondly, and closely related to the resource base potential,[17] the population density in the US where shale gas and shale oil resources have been developed is relatively low. Consequently, shale development has not been a great enough disturbance to the interests of the local population, with result that the 'not in my backyard' (NIMBY) arguments have yet to be triggered in most areas.

Thirdly, there have generally been ample water resources available for use in hydrofracs, which is critical for shale gas development.

Fourthly, no technological innovation would have been possible without long-term government financing of fundamental research and development (R&D) efforts laying the foundation for further commercialisation of obtained results by the private sector. In his State of the Union Address in January 2012, President Obama stated that 'innovation is what America has always been about. … Innovation also demands basic research. … Support the same kind of research and innovation that led to the computer chip and the Internet [i.e. into technological breakthroughs and revolutionary changes] … And nowhere is the promise of innovation greater than in American-made energy. … This country needs an all-out, all-of-the-above strategy that develops every available source of American energy … it was public research dollars, over the course of 30 years, that helped develop the technologies to extract all this natural gas out of shale rock – reminding us that government support is critical in helping businesses get new energy ideas off the ground. … Now, what's true for natural gas is just as true for clean energy. … Our experience with shale gas, our experience with natural gas, shows us that the payoffs on these public investments don't always come right away. Some technologies don't pan out; some companies fail. … Pass clean energy tax credits. … We can also spur energy innovation with new incentives.'[18]

Thus, it was long-term innovation and investment, based on and backed up by state money (public funding), that led to a success in shale gas development (see figure 4.5).

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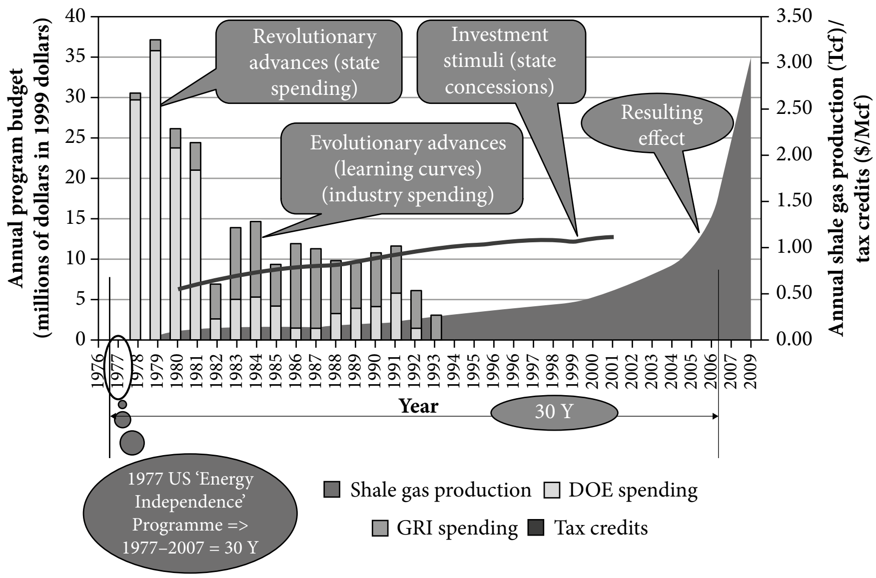
17 This is why I place it here, which does not necessarily means it has second place in the hierarchy of factors influencing the US shale gas revolution.

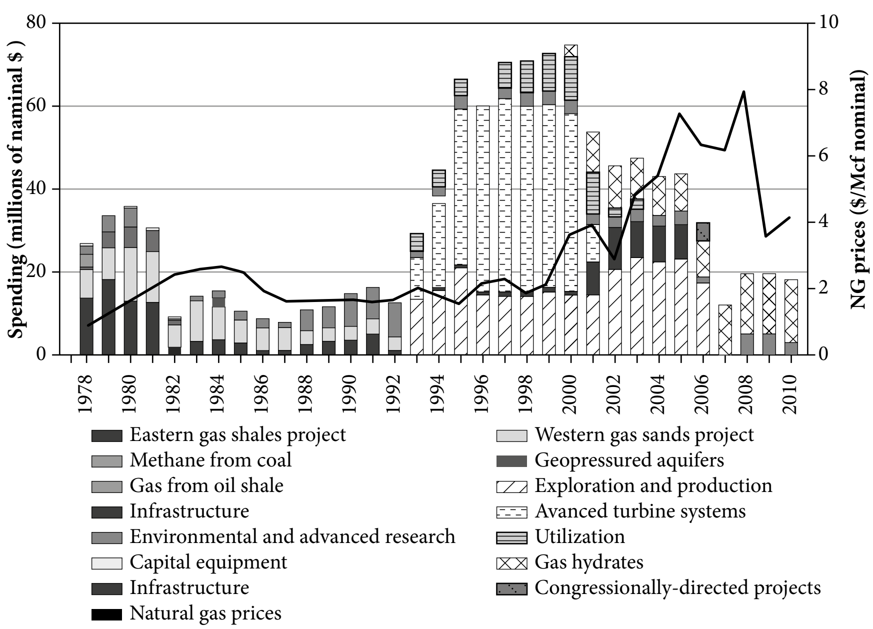
18 'Remarks by the President in State of the Union Address, January 24, 2012', United States Capitol, Washington, DC <https://www.whitehouse.gov/the-press-office/2012/01/24/remarks-president-state-union-address>.

Figure 4.5. Role of US state financing in stimulating the 'US shale gas revolution' (based on MIT study)



Source of the basic figure: Figure 8.1 'CBM RD&D Spending & Supporting Policy Mechanisms' from *The Future of Natural Gas. An Interdisciplinary MIT Study*, 2011, p. 163; figure adapted by author.

Figure 4.6. US DOE natural gas research funding history (according to MIT)



Source: Figure 8.3 with the same title from *The Future of Natural Gas. An Interdisciplinary MIT Study*, 2011, p. 167, with references to DOE Office of fossil Energy.

But this investment was not immediately aimed at shale gas originally. Rather, it was generated by the 1977 US 'Energy Independence' programme, which envisaged committing large amounts of public money from 1978 to multiple energy disciplines with potential commercial prospects, in order to diminish US energy import dependence. At later stages this public funding was accompanied by investment from the industry. In gas-related areas, such state financing of research, demonstration and development (RD&D) covered a broad range of disciplines (see figure 4.6).

This type of public-private partnership, especially in RD&D financing, was not confined to shale gas development. Similar types of state and industry support (though at a lower scale but with earlier and more large-scale commercial results) were provided, for example, for the US coal-bed methane (CBM) production (see figure 4.7). A MIT study noted that '[t]he interplay of early DOE funding, industry-matched GRI [Gas Research Institute] applied RD&D and synergistic policy incentives had a material impact on U.S. unconventional natural gas development. … The DOE funding was focused on reservoir characterization and basic science. GRI implemented industry-led technology roadmaps leading to demonstration. This overlapped with a time-limited tax credit put in place for wells drilled from 1980 to 1992, with their production eligible for the credit through 2002. The results of this multi-pronged approach to public-private RD&D and deployment are particularly striking for CBM.'[19]

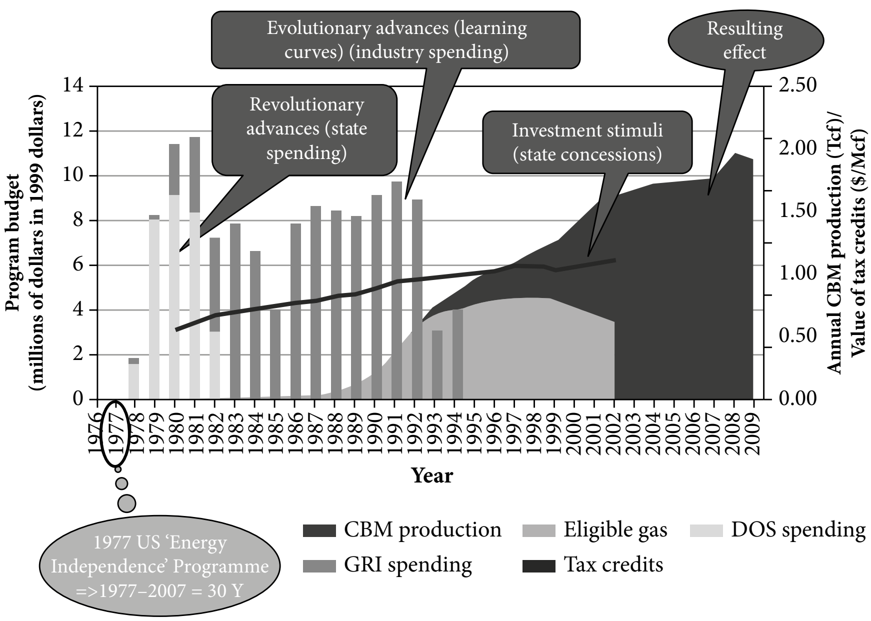
These activities took place in a country where the economy is considered to be one of the most liberal in the world, demonstrating that it is incorrect to assume that the role of state in the US is limited to minimum. Nevertheless, it took 30 years before all the investment and R&D measures, starting with state financing of RD&D and public-private partnership, has provided their effect – an explosive growth of shale gas production in US and consequential multiple domino effects of US shale gas revolution.

Fifth, the US managed to transform the negatives relating to the historical path of its oil industry development into positives today, which enabled the quick and wide development of shale hydrocarbons. It is universally recognised that the US pioneered development of traditional oil resources in 1959 with the discovery of oil in Pennsylvania. Insufficient knowledge at the time about formation geology led to a licensing system in a 'wild capitalism' environment (in the era of robber-baron capitalism), implemented through tendering a multitude of small blocks to individual entrepreneurs who were competing with each other and had no idea at that time that by individualised (non-coordinated) development of their acreages they would destroy the petroleum field's hydrodynamics. Such uncoordinated and non-optimal field development in early conventional petroleum era (which usually deviated from

19 'The Future of Natural Gas. An Interdisciplinary MIT Study', 2011, p. 163.

the maximum efficient recovery rate (MERR) – the parameter which justifies optimum development of the deposit from economic and geologic perspective, its most effective monetization in the long-term) resulted in a rapid decline of oil well production rates, thereby requiring excessive drilling to boost overall production in the decades to come. As a result, until the early 1980s 85% of the total world's development wells were concentrated in the US, with the majority of these being low-yield stripper wells. But this very situation stimulated development of the oil service industry to create a highly efficient, diversified industry that is adequate for the current conditions, with its focus on cost-cutting to ensure that well operation costs (the main element of production costs) in the US are 60–80% lower than in any other country. The US has the highest accumulation/concentration of available equipment (drilling rigs, etc.) in the world, and is therefore able to quickly react to demands from the shale resource owners to start drilling in new areas. This availability of technological equipment has ensured that there is no delay in drilling and well service/completions, thereby ensuring that an equipment supply bottleneck would not have been responsible for preventing or slowing down shale gas development.

Figure 4.7. Role of US state financing in stimulating coal-bed methane US production (based on MIT study)



Source of the basic figure: Figure 8.2 'Shale Gas RD&D Spending & Supporting Policy Mechanisms' from *The Future of Natural Gas. An Interdisciplinary MIT Study*, 2011, p. 163; figure adapted by author.

The *sixth* factor is the US liberal economic model. Over 4,000 oil and gas companies are operating in the US today, most of them – non-integrated medium and small companies. For comparison, today in Russia, a country larger than the US in geographical terms, the number of independent (non-affiliated with Russian majors) small and medium-sized companies is around 250, compared to 108 at the end of the 1990s.[20] The large number of US small and medium-sized shale fields predefines (within such US liberal economic model) the appearance of big amount of small and medium risk-taking companies aimed to develop such fields which prevents any monopolistic control over the industry and provides a rapid response to new challenges and an ability to undertake the necessary 'pioneering' risks. This differs from big businesses, which generally dominate the conventional petroleum industry and are traditionally plagued by inertia and lengthy decision-making procedures.

The *seventh* factor is the US's subsoil resources management system, under which landowners have the ownership rights to the subsoil resources. Unlike other countries, US landowners receive the resource rent directly (lease payments for the right to use their subsoil resources), instead of the government, unlike in systems where the latter is the owner of the subsoil resource. This has the effect of encouraging landowners to lease out their land to subsoil users (the oil and gas companies interested in developing the shale gas resources), without lengthy bureaucratic procedures. The same situation encourages the subsoil users' development of the subsoil resources in the quickest possible time, since licence contracts usually contain provisions requiring an intense development programme, and any failure to comply with it leads to the termination or cancellation of the lease contract.

The *eighth* factor is the existing extensive pipeline network with competitive, open (transparent) and non-discriminatory access.[21] This pipeline system with open access enables a producer and/or consumer to acquire mutual access and thereby capitalise (monetise) any effect of the development of new fields. Moreover, general development of infrastructure (both macro-economic and energy-related) has stimulated the development of shale gas projects.

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20 According to Elena Korzun, General Director of Association of Small and Medium Non-Integrated Oil & Gas Companies 'Assoneft' (Третья нефтяная сила. – "Нефть и газ", тематическое приложение к газете Коммерсантъ, 16.6.2015, с.13 / The Third Oil Power, 'Oil & Gas', Thematic Supplement to Kommersant Newspaper, 16.6.2015, p. 13).

21 The regulatory regime of US gas pipeline system and its evolution are examined in detail, *inter alia*, in the recent monograph of the Institute of World Economy and International Relations named after E.M. Primakov, Russian Academy of Sciences (IMEMO RAS): I. Kopytin, A. Maslennikov and M. Sinitsyn, *USA: The Problems of Integration of Gas and Electricity Markets*, ed. by S. Zhukov and V. Tatsiy, Master, Moscow, 2014, 334 p. (И.А. Копытин, А.О. Масленников, М.В. Синицын. "США: проблемы интеграции рынков природного газа и электроэнергии" / под ред. С.В.Жукова и В.В.Тация. – М.: Магистр, 2014, 334 стр.). This author has published a well-deserved complimentary review of this book: A. Konoplyanik, 'A Very Timely Book' (2015) 13–14 *Oil and Gas Vertical* 44–45. (А. Конопляник. Очень своевременная книга. – "Нефтегазовая Вертикаль", 2015, № 13–14, с.44–45).

Ninth, the US has a well-developed financial system. On the one hand, the well-developed financial system in the US ensured the availability of cheap and affordable credit, which was required for the debt financing of oil and gas projects. On the other hand, this enabled financial profits to be retained for future periods through the use of the futures markets and financial derivatives by hedging and reinsuring against lower production through the use of future periods. At the same time, the financial debt bubble kept growing, a bubble that has of course been known to disappear or burst in the course of time (we'll address this issue in more details later).

Tenth, in the US there are strong tax and investment incentives and similar measures of direct state support to industry (see figures 4.5, 4.6 and 4.7). When a nation is striving to achieve energy independence or a similarly ambitious target, it requires huge investments, which should be done in cooperation rather than rivalry between the state and the private sector. As noted above, private and public funding of R&D occurred, often entering into public-private partnerships. Such collaboration ensured that there were great breakthroughs in the development of techniques that ultimately proved useful for shale gas development.

Finally,[22] there is the element of the *ignorance advantage* enjoyed by any pioneer at an early stage of the learning curve, when he is unaware of any negative consequences of new technologies. This often refers to possible environmental damage that can be recognised and categorise as real or false only in the course of further operations. Shale gas development is no exception to this. As the long-term risks or negative consequences remain relatively unknown, there are no additional costs associated with the complication of any licensing procedures designed to prevent such negative consequences (whether real or invented/virtual).

In agreement with the words of Dan Yergin, an esteemed author writing on energy issues and whose fundamental research on global history of the oil industry resulted in his excellent book *The Prize* being awarded the Pulitzer Prize, 'such [a] combination of factors cannot be found elsewhere in the world'.[23] For this reason, shale oil and gas development in other countries, whether in Europe or Asia, will not change the global energy landscape. It is only the US shale gas revolution, for the reasons stated above, that will be a global revolution. All other shale gas developments in other countries are likely to have only local impacts.

Yergin's opinion was echoed by another well-known expert, Philip Verleger Jr, who noted that 'unique institutional conditions forming the foundation

22 However, one can find additional arguments/explanations for the reasons why US has succeeded in theUS shale gas/oil revolution while others have not.

23 Citation of D. Yergin, in S. Pfeifer, 'Finds that form a bedrock of hope', *Financial Times* shale gas series, 22.4.2012.

of the American shale revolution, cannot be found elsewhere',[24] with which the author concurs. According to Verleger Jr, the US and Canada remain the only countries supporting the development of small, efficient, low-cost energy companies that are required to drill thousands of low-cost wells in order to develop shale gas resources, whereas other countries rely on energy giants such as ExxonMobil, Chevron and BP. These major transnational corporations are unable to implement projects involving thousands of workers at numerous minor fields since this is not their core competence. Rather, they succeed in developing a small number of very costly and high-yield mega-projects, which rely on developing economies of scale. In order for countries outside the US to excel at developing shale gas resources, either these countries will need to support the development of small to medium-sized enterprises efficient in drilling low-cost wells, or oil majors such as BP and Chevron will need to re-examine and redevelop their business model into a low-cost and highly efficient system capable of undertaking the thousands of wells required for shale gas development.

3. WHY NOT IN EUROPE? WHY NOT IN CHINA? WHY NOT ELSEWHERE?

Let's start with a conspicuous illustration – the random sampling. On 15 January, 2014, among mass-media available in the business lounge of Brussels airport this author has discovered four publications on shale hydrocarbons in two available English-language newspapers and one magazine of a general political and business character. The *Bloomberg Business Week*,[25] carried an account of how hydrofracs and horizontal drilling in the US reversed the downward trend of oil extraction in the country and caused growth (by 30% in Texas in the year September 2012 to September 2013). Similarly, an article in the *European Voice*[26] stated that tightening EU environmental legislation (concerning the requirements to assessment of environmental impacts of the projects) did *not* affect shale gas drilling, as EU member countries did not support a relevant proposal of the European Parliament and it was not included into the agreed amendments. Thus, shale gas was actually given preference for investment (since any environmental assessment costs quite a lot of money, plus the internationally accepted 'polluter pays' principle works in EU). At the same time, there were two articles in the *International New York Times* on the virtual collapse of the shale industry in Europe. One article, contributed by the well-known energy

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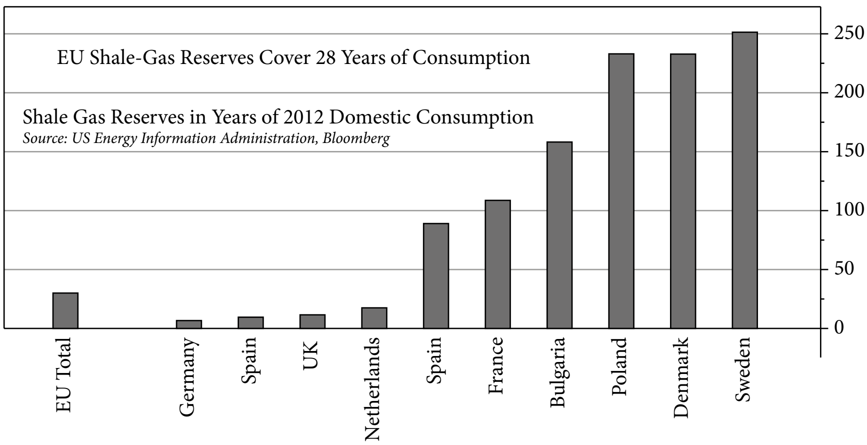
24 P.K. Verleger Jr, 'The coming US boom and how shale gas will fuel it', *Financial Times*, 25.4.2012.

25 '8 1/2 Success Stories of the Year', *Bloomberg Business Week*, 23.12.2013 – 5.1.2014, p. 11.

26 *European Voice*, 9.1.2014.

economist Professor Paul Stephens,[27] was titled 'Why Shale Gas Will Never Conquer Europe',[28] while the other article (titled 'ENI withdraws from shale projects in Poland on disappointing drilling results') contained an account of the energy companies' disappointments and withdrawals from shale projects in Europe.[29] Both articles painted a similar picture: Europe is no USA, and no replication of the American shale revolution is possible in Europe. Politicians appear disappointed; businesses write off losses; expectations are frustrated.

Figure 4.8. EU shale gas: where overestimated expectations came from…



Note: US DOE EIA has been publishing estimates of 'technically recoverable shale gas resources', but not its 'reserves' estimates, as mentioned by the authors of the cited article, since "reserves" presents only a portion of a broader 'resource' category (see Box 1).
Source: L. Mortkowitz Baverova, 'Europe has 28-Year Shale Gas Rebuff to Russia: Chart of the Day', *Bloomberg Business*, 19.5.2014 <http://www.bloomberg.com/news/articles/2014-05-19/europe-has-28-year-shale-gas-rebuff-to-russia-chart-of-the-day>.

Moreover, in May 2015 Bloomberg published an article that confirmed Russia's long-held position on the US shale gas revolution: 'Russia Was Right: Shale in Europe Has Proved a Dud'.[30] As they say in math – QED.[31] However, one year before this article was published, in May 2014, Bloomberg published an article by the same author, stating that the EU 'has enough gas in shale formations to

27 Professor Paul Stephens is from the London-based Royal Institute of International Relations (Chatham House) and the Centre for Energy, Petroleum and Mineral Law & Policy, University of Dundee, Dundee, Scotland.

28 P. Stephens, 'Why Shale Gas Will Never Conquer Europe', *International New York Times*, 15.1.2014, p. 6.

29 'ENI withdraws from shale projects in Poland on disappointing drilling results', *International New York Times*, 15.1.2014, p. 14.

30 L. Mortkowitz Bauerova, 'Russia Was Right: Shale in Europe Has Proved a Dud', *Bloomberg Business*, 11.5.2015 <www.bloomberg.com/news/articles/2015–05–11/russia-was-right-shale-in-europe-has-proved-a-dud>.

31 QED = 'quod erat demonstrandum' (which was to be proved).

free this bloc from dependence on Russian energy supplies for 28 years'.[32] She immediately made a qualifying remark, stating that this would occur 'only if corresponding states are ready to extract it' (see figure 4.8). Such a qualification is similar to an earlier *Financial Times* statement (see figure 4.4). Within a year, both Bauerova and Bloomberg were obliged to acknowledge: 'No, they [the EU states] are not ready'. And I will add to this: and they would not be ready for long due to objective reasons…

Where did this early overestimation come from? The author of the 2014 Bloomberg article repeated the same mistake of numerous publications of 'specialist' energy authors, who are in reality not specialists in the technological, economical, financial, investment or legal problems in energy.33 Hence, when these authors assess levels of domestic consumption of domestic resource bases for different EU states, they mix up different economic categories of non-renewable energy resources (technically recoverable and economically recoverable resources), something that professional energy economist will never do. In other words, they make economic assessments of probable shale gas resources, which is not an economic category (and this is why it provides much higher quantitative values), as opposed to proved recoverable reserves (which is an economic category and thus is much smaller in values than all resources estimates – see Box 1 for an explanation). In doing so the authors compare the uncomparable, even though it is essential to compare like with like. Consequently, calculated in such way an assessment of possible self-coverage of EU gas consumption by domestic shale gas became speculative (or propagandist – since became immediately overstated) and not practical. It has created overstated expectations within broad groups of EU citizens. But overstated expectations be fraught with great disappointments. And this is what has been happening now in the EU regarding its shale gas.

If one compares the US and the EU preconditions for gas market developments, including for shale, it is inevitable to draw the conclusion that institutional and structural factors differ greatly between the two,[34] thereby making a replication of the US shale gas revolution in the EU impossible.[35]

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32 L. Mortkowitz Bauerova, 'Europe Has 28-Year Shale Gas Rebuff to Reussia: Chart of the Day', *Bloomberg Business*, 19.5.2014 <www.bloomberg.com/news/articles/2014–05–19/europe-has-28-year-shale-gas-rebuff-to-russia-chart-of-the-day>.

33 Energy topics have become especially important in recent years in the works of different sorts of 'politologists', who usually emphasise in their 'analytical constructions' different conspiracy theories, consider energy as a 'weapon', etc., but very frequently also demonstrate lack of corresponding technical, economical, financial or legal knowledge relating to development and operation of capital-intensive energy projects with long-term physical and economic lifecycles.

34 See 'Will Gas Follow Oil to Become a Global Commodity?' (Chapter 4.1, pp. 99–102) and Table 4 (p. 102) in R. Dickel, G. Gunul, T. Gould, J. Jensen, M. Kanai, A. Konoplyanik and Y. Selivanova (*supra* n. 16).

35 See also this author's publications and presentations on this issue in the in the footnote 1 at the start of this chapter.

In the case of China, at least three major factors will prevent China from replicating the shale gas revolution. These factors are: (i) much higher density of population, (ii) a risky earthquake/seismic environment, especially in Sichuan province (the most prospective for shale development in China), and (iii) a lack/deficit of water resources in highly populated Chinese provinces.

It seems that China, and expert authors commenting on shale prospectivity in China, envisaged a bright future for China shale oil development. In particular, some observers noted that China is likely to be the second economy that will replicate the US shale gas revolution domestically, particularly since China possesses, according to some estimates, abundant geological shale gas resources which are the highest in the world (see figures 4.2–4.4). However, an energy and law professor from the Centre for Energy, Petroleum & Mineral Law and Policy (CEPMLP, University of Dundee, Scotland) has mentioned at the Energy Transitions Conference in Joensuu, Finland (February 2015) as if Chinese Government has recently almost twice diminished official shale resources estimates.[36] If this information was correct (which basically went in line with the common economic logic, based on the well-known by petroleum engineers and energy economists so-called 'Arps diagram' about changes in resources/reserves estimates within the time-frame), it will prove a cause-and-effect relationship with finalization some time prior to that of the Russia-Chinese talks on long-term gas supply/sales contract of Russian gas to China and its pricing formula. The shale gas factor during these negotiations had a direct price effect since perceived prospective availability of domestic shale gas in China was possibly a perceived expected 'softener' of Russian position on gas price formula. Now that negotiations have concluded, there is no need for China to overstate its shale resource estimates.

Thus, predominantly institutional factors are behind the conclusion that replication of the US shale revolution is impossible in other countries. However, if the US shale revolution cannot be replicated outside that country (at least at a similar scale and pace) for institutional reasons, what are the 'revolutionary' global domino effects of US shale gas development?

4. DOMINO EFFECTS OF THE US SHALE GAS REVOLUTION

The US shale gas and oil revolution has triggered a chain reaction of irreversible processes, which have impacted on related industries and activities on the global

36 Компромисс на конце трубы. Является ли отказ от "Южного потока" "эмоциональной реакцией" на санкции или частью долгосрочной стратегии развития российского НГК? – *"Нефть России"*, 2015, №3, с. 4–8 (часть 1); №4, с. 4–9 (часть 2) ('Compromise at the end of the pipe. Whether cancellation of "South Stream" is an emotional reaction on sanctions, or it is a part of long-term strategy of Russian energy complex?' (2015) 3 *Oil of Russia* 4–8 (part 1) and (2015) 4 *Oil of Russia* 4–9 (part 2)).

scale. An explosive growth in shale gas extraction in the US has led to excessive supply of gas with a concomitant fall in gas prices in the US, since until first US LNG export in February 2016 USA were in fact 'the energy island'. Domestic gas has become financially more attractive than imported gas. Therefore the demand for imported gas has radically decreased in the US. As a result, the 'matrix effect' has come into play, where a change of parameters in one cell of a matrix causes changes of the line and column totals, and therefore, the formation of a new matrix. The scale of the US shale matrix is enormous, being played out on a global scale, with both direct and indirect impacts and consequences.

– The *first* effect is that the US gas market has been transformed from a deficit to proficit market, from a seller's to a buyer's one. Saturation of the domestic market by domestically produced gas and its continuous supply, with opportunities for its export not yet available (until early 2016), has also lead to an inescapable decline in the domestic gas price (which reached the historical low of US$2/MMBtu (million British thermal units) in May 2012 and then again in June 2015). This lower price has increased the competitiveness of US manufacturing industries, especially energy-intensive sectors, due to a decline in energy costs within the overall cost structure. However, at the same time it has created problems for the US shale gas producers themselves. The direct consequences of the US shale gas revolution on the US gas market are evident, with a stable transformation of the US from a gas importer to a gas exporter in three stages. First, there was the steady (and then from the mid-2000s rocketing) growth of US domestic gas production. This in turn led to the cancellation of gas imports from the end of the 2000s. Finally, the US energy economy has been transformed from an importer of LNG (liquid natural gas) to its exporter (from 2016 onwards).

– The *second* effect, this time for Europe (and for oil indexation), has been that the closure of the US gas import market (apart from Canadian imports) has reversed the LNG export flows in the Atlantic and redirected previous US-destined cargoes (predominantly from Qatar) to Europe. This has led to excess supply in the European gas market, coupled with a fall in demand due to the economic crisis, energy efficiency measures and the development of subsidised renewables.[37] Excessive supply has led to the active development of spot sales and the spot and futures market, especially in the UK and north-western Europe, where the gas supply infrastructure is best developed. The EU Third Energy Package has also dramatically reshaped the EU gas market architecture by introducing a system of 'entry-exit' (pool-type) market zones with spot-trade centres (virtual trading platforms) in each. It is suggested that without the American shale revolution, gas industry reform in Europe based on the Third Energy Package would have been at least very uncertain.

[37] A. Konoplyanik, 'Russian gas in Europe: Why adaptation is inevitable'– (2012) 1(1) *Energy Strategy Reviews* 42–56 <www.sciencedirect.com/science/article/pii/S2211467X12000119>.

The excessive gas supply in Europe as a result of the US shale revolution has had a significant and irreversible impact on the contract system and pricing mechanisms of pipeline gas supplies to Europe from gas exporters, including Russia, Norway, Algeria and Qatar. A growing number of suppliers are fighting to retain purchasers in a shrinking market; price-cutting (bordering on actual price dumping) has commenced amid a wider choice of alternative suppliers for the buyers. Exporters have to review their contracts, soften the terms, introduce price discounts (including retroactive recalculations based on decisions of arbitration tribunals), and move away from the oil indexation (in Europe, oil products indexation) of gas prices.[38] As a result, today half (or even more) of the gas in the EU is traded at gas indexation linking gas price to the quotations at most liquid EU hubs such as the Title Transfer Facility (TTF) in Netherlands and National Balancing Point (NBP) in the UK, compared to ten years ago, where three-quarters of contractual deliveries of gas in Europe were based on petroleum products indexation. This is the most important domino effect of the US shale revolution to date. Such an impact has had a major practical significance for Russia, one of the key gas exporters to the EU. Moreover, one can assume that without the US shale gas revolution, adaptation of Gazprom's contractual structures and pricing mechanisms on the European gas market (and the same of other major suppliers to the EU) would have commenced much later.[39]

One should note that the countries extracting associated gas (Norway or the UK) or gas with high liquid content (Qatar) can afford to sell the gas below cost, as any losses (or missed revenues) from the low-price gas sales can be easily compensated for by selling liquid hydrocarbons at prices that stayed high on the oil market until the end of 2014. Thus the situation is much more difficult for Russia (particular Gazprom), which continues to extract mostly dry gas from huge Cenomanian fields in an attempt to build up an economy of scale. However, due to the 'single commodity' nature of most of Russian gas production and export, opportunities for price manoeuvrability are quite limited as compared to suppliers of the EU market that sell gas as a by-product of oil extraction (associated gas).

– The *third* effect, for Asia (and for oil indexation), is that the growth of shale gas extraction in the US and concomitant export of LNG from 2016 from the Sabine Pass export terminal will occur at the same time that the planned third-stage refurbishment of the Panama Channel is due for completion, enabling LNG tankers to use the Panama Canal. The first deliveries of US LNG have already

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38 A. Konoplyanik, 'Gazprom's concessions in oil-indexed long-term contracts reflect "forced adaptation" to new realities',– (2011) *Gas Matters* 26–28.

39 А. Конопляник.Сланцевый газ: не конкурент, но стимулятор реформы экспортного ценообразования Газпрома (комментарий к статье К.Барыщ "Сланцевый газ и энергобезопасность Евросоюза"). – "Нефтегазовая Вертикаль", 2010 г., № 18, с. 28–29 (A. Konoplyanik, 'Shale gas: not a competitor, but a stipulator of reform of Gazprom's gas export pricing' (commentary to K. Barysch, 'Shale gas and EU energy security') (2010) 18 *Oil & Gas Vertical* 28–29).

been contracted in the Asia-Pacific region, where hungry Asian markets have meant that LNG contract prices are the highest in the world, primarily because they remain tied to the oil prices (this situation was valid until at least end of 2014 when oil prices began to sharply decline). However, the American LNG contract price formula is different, at least in the first three approved contracts, as it is tied to the US Henry Hub spot market price.

Competition between two contract pricing formulas has commenced in the Asia-Pacific market, where formulas are based on different pricing models and behaviour patterns: (i) oil price indexation under standard Asia-Pacific LNG pricing formula (replacement-value based pricing) and (ii) gas price indexation, indexed to the Henry Hub price (cost-plus-based pricing).[40] In the former case, the LNG price is tied to the world market oil price, determined by major global non-oil traders (i.e. global financial market players that are predominantly major American investment banks). Their global investment portfolios include, *inter alia*, numerous oil securities (oil-based financial derivatives), while the 'paper' oil market (futures contracts and their derivatives) long ago became a component of the global financial market. Consequently, until the end of 2014 oil price fluctuations were determined by the 'horizontal' flows of liquid capital between different segments of the global capital market, including inflows to and outflows from the 'paper' oil market.[41] In the latter case, the LNG price is tied to the US Henry Hub gas (national spot trade centre) price, and movements are determined by the gas supply and demand balance in the US market (which until early 2016 was mostly an isolated 'energy island' in gas).

Until the end of 2014 oil-indexed LNG prices in the Asia-Pacific region were much higher than the expected Henry Hub-based LNG prices of future US deliveries. Attractive prices on the Asia-Pacific market (Asian premium) further rose after the Fukushima nuclear incident in 2011, thus providing a ready market for newly developing LNG projects. However, now the not-yet contracted market niche for LNG is rapidly shrinking, placing the Asia-Pacific market in a situation that may replicate the situation earlier witnessed in Europe when excess supply forced exporters into price cuts, contract restructuring, and a significant reduction of the share of oil-indexed contractual supplies which lost its competitive niche to spot trade with lower (in the buyer's market) prices. If excess supply (slowing demand and growing supply attracted by comparatively

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40 For explanation of differences in gas pricing mechanisms see: R. Dickel, G. Gunul, T. Gould, J. Jensen, M. Kanai, A. Konoplyanik and Y. Selivanova (*supra* n. 17).

41 А. Конопляник. Кто определяет цену нефти? Ответ на этот вопрос позволяет прогнозировать будущее рынка "черного золота". – *"Нефть России"*, 2009, № 3, с. 7–12; № 4, с. 7–11 (A. Konoplyanik, 'Who Determines the Price of Oil? The Answer to This Question Helps to Foresee the Future of "Black Gold" Market"' (2009) 3 *Oil of Russia* 7–12 and (2009) 4 *Oil of Russia* 7–11); В.В. Бушуев, А.А. Конопляник, Я.М. Миркин и др. Цены на нефть: анализ, тенденции, прогноз. – М:, ИД "Энергия", 2013, 344 стр. (V. Bushuev, A. Konoplyanik, Ya. Mirkin, *Oil Prices: Analysis, Trends, Forecast*, Energia (Energy) Publishing House, Moscow, 2013, 344 p.).

high prices prior to end-2014 during which period final investment decisions (FID) on most of new LNG export projects now on-stream were taken) emerges on the Asia-Pacific market, this may trigger a massive transition from oil indexation to Henry Hub indexation, initiated and lead by consumers. To start such a downward price trend, the oversupply need not be great. The unfavourable consequences for Russia of such a scenario are obvious: projects targeted at the Asia-Pacific market may prove unprofitable. According to Tatyana Mitrova (Deloitte has come to a similar conclusion),[42] 'gas supplies from the USA may not only press more expensive projects (for example, Australian or Russian) out of the market, but will most probably play a key role in development of new approaches to LNG pricing globally, and in transition to the spot price peg in the long term'.[43] At the same time, this creates strong incentives to focus priorities on comprehensive cost cutting along the entire supply chain through the implementation of revolutionary areas of technological advances, which will require a policy review in the field of creating a favourable investment climate.

The clear picture of competitiveness between two pricing mechanisms for LNG in Asia Pacific which existed during the period of high oil prices prior to end-2014, when US LNG (if exported already at that time) would have clear competitive advantage due to its pricing formula which index US LNG export price (Asia Pacific LNG import price from the US) to domestic gas price at the oversupplied US gas market, was smashed by the fall of international oil prices beyond that date. The first analytical results of new competitiveness between replacement-value-based LNG pricing model (LNG import price linked to Japan Crude Cocktail/Japan Customs Clearing crude oil price (JCC)) and cost-plus-based LNG pricing model (LNG import price linked to US Henry Hub gas price) in Asia Pacific shows that, if the standard LNG contract slope is taken equal to 13–16%, price-competitive zone of US LNG in Asia Pacific is located in the values from above 50–60 USD/bbl oil price (if the Henry Hub price is equal to 2 USD/MMBTU, the lowest gas price experienced in US gas market in recent years) to above 80–100 USD/bbl oil price (if the Henry Hub price is equal to 6 USD/MMBTU, the highest gas price experienced in US gas market in recent years, in which direction it will most probably move with the start and further expansion of US LNG export).[44] But will international oil price of $100/barrel or higher return (incl. in the foreseeable future)?

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42 'Exporting the American Renaissance. Global impacts of LNG exports from the United States', Report by the Deloitte Center for Energy Solutions and Deloitte Market Point LLC, Deloitte Center, 2013, 24 pp.

43 Т.А. Митрова. Перспективы развития экспорта СПГ из Северной Америки и его влияние на мировые газовые рынки. "Энергетическая политика", 2012, №6, с.30–41 (T. Mitrova, 'LNG export development prospects from North America and its influence on world gas markets' (2012) 6 *Energeticheskaya Politika (Energy Policy)* 30–41).

44 А.А. КОНОПЛЯНИК, ДЖИНСОК СУН. 'Границы конкурентоспособности контрактных поставок на рынке СПГ в АТР при разных механизмах ценообразования: нет-бэк от стоимости замещения в АТР (нефтяная привязка – к JCC) vs. кост-плюс

– The *fourth* effect is on the formation of a global single gas market. Upon becoming a gas exporter, the US is to become the second largest LNG global arbitrageur after Qatar, that is an exporting nation that will be able to operate simultaneously in the Atlantic and Asia-Pacific markets. This will accelerate the irrevocable process of the global gas market formation, comprising regional pipeline gas markets united by LNG supplies, and where the global arbitrageurs will play the role of certain market regulators in regional segments (as already happened with Qatari LNG flows which flowed into the EU in 2009 after the closure of US gas market for imported gas; this has dropped spot gas prices in EU; but post-2011 reorientation of Qatari LNG from the EU to Japan for higher premium after Fukushima accident has raised back the EU spot gas prices). The third arbitrageur, though at a later stage, might be the offshore gas fields of Eastern Africa.

– The *fifth* effect is that the shale revolution is extending the era of hydrocarbons. This makes the 'peak oil' theory (based on Marion King Hubbert's theory and his Hubbert curve) even more irrelevant. Formerly unprofitable shale gas and oil resources have transformed from the 'unconventional' to the 'traditional' category of resources. That is, they have moved under the Hubbert curve, shifting the curve's peak upwards and to the right (see Box 2).

– The *sixth* effect has been on coal. Cheap US gas has started to replace expensive (by US standards) coal in the US fossil fuels balance. The coal went to Europe, where, becoming cheap (by European standards), it successfully competed (i.e. in electricity generation) with the more expensive petroleum products-indexed contractual pipeline gas (i.e. mainly Russian gas), replacing it in competitive segments. This is the second wave of price pressure on the pipeline gas exporters with contracts pegged to petroleum product prices, squeezing them out of their competition niches (the first wave came from gas oversupply). Here the commercial interests contradict the stated long-term political objectives of the European Union in reducing the negative environmental impact, as a cleaner fuel (gas) is being replaced by a dirtier one (coal).

– The *seventh* effect has been on the environment. A reduction in coal consumption in the US, and replacement of coal with gas, has reduced US CO_2 emissions. The reverse has occurred in the EU, as the growth in coal consumption and its replacement of gas in Europe has lead it to an actual (though not statistical, due to the trade in emission quotas) growth of emissions.

(газовая привязка – к Henry Hub).' Выступление на международной конференции "СПГ Конгресс Россия 2016", 16–18 апреля 2016 г., Балчуг Кемпински, Москва (www.konoplyanik.ru/speeches/160317-Конопляник-Сун-СПГ%20России%20Конгресс%202016.pdf); A.A. KONOPLYANIK, JINSOK SUNG. 'APR LNG competitiveness borders within various price models: netback replacement value in APR (Oil indexation – to JCC) vs. cost plus (Gas indexation – to Henry Hub)'. Presentation at the LNG Russia Congress 2016, 16–18 March 2016, Baltschug Kempinski Hotel, Moscow (www.konoplyanik.ru/speeches/160317-Konoplyanik-Sung-LNG%20Russia%20Congress%202016-ENGL.pdf).

European economic and energy policies have a distinct environmental component and appear to be in favour of a clean environment. However, as soon as it turned out to be much more profitable to consume cheaper imported US coal (forced out to Europe by the growth of American shale gas), rather than more expensive pipeline gas pegged to oil product prices, Europe immediately forgot about its fight for the environment and started fighting for direct commercial profits from major commercial taxpayers. Essentially, European processes related to the environment are the reverse of that in the US. Of course, there is the emission quota trade securing, within a specific statistical framework (actual emissions plus/minus the 'accounting balance' of emission quotas trade), the demonstrated reduction or stable 'paper' emissions (due to the emission quotas trade balance), when they are actually growing in the region (as a result of replacement of the cleaner gas by the dirtier coal). However, when referring to actual emission, the US is rather reducing CO_2 emissions by replacing coal with the shale gas, while Europe, having publicised its environmental objectives, is, on the contrary, increasing its actual CO_2 emissions.

The commercial interests of EU officials (who look the other way when it comes to the substitution of dirtier coal for cleaner gas) are obviously dominant. When a government sees that national companies (national champions) who expected to pay income taxes are unable to do so because their income is below zero, it rushes to protect its major taxpayers, including, of course, gas companies. The major form of taxation in Europe is income tax; therefore, when incomes fall, tax payments also fall. However, the revenue from income tax is in great demand in times of crisis. How to balance this newly appeared contradiction between commercial interests of the EU states and their companies, on the one hand, and proclaimed political objectives of the EU in the environment-protection sphere, on the other hand, as a domino effect of US shale gas revolution? In the meantime, greenhouse gas emissions do not grow because companies start to buy quotas abroad. So everything appears fine on paper, while in reality it is not.

– The *eighth* effect has been on shale oil. The successful development of shale gas and the reduction in its price in the US have led to a shift in focus from dry to wet gas and shale oil, which can improve the financial performance of the industry. As a result, the US have pioneered not only shale gas, but also shale oil development, motivated by a pressing need to overcome the growing debt crisis of American companies involved in the shale gas development (see below). Thus, it appears that shale gas extraction was rather needed first to produce associated liquid fractions which were priced higher than gas. Successes in wet shale gas development opened the door for a US shale oil revolution.

– The *ninth* effect has been on the global oil market. This effect is twofold, though both components are interrelated: (i) the growing role of the US in the global oil market, and (ii) the changing/evolving nature of the innovation and technological cycle in hydrocarbon industries.

Growing shale oil production in the US has increased the nation's influence on the global oil market. With two distinct segments of the market (physical oil and paper oil), the oil market remains bipolar, with the Saudis dominating the physical oil market and the US dominating the paper oil market.[45] Since 2005 the US net import of liquid fuels has been steadily diminishing, with the US set to be a net exporter of liquid fuels (BP expects this to happen around 2030).[46] If the US remains both a dominant player in the paper oil market and an emerging player in the physical oil market, it is possible that there may be a transition of today's bipolar global oil market into unipolar one,[47] dominated by the US.

This logic is nothing to do with politics or conspiracy theories. Rather it is purely economic. Oversupply in the US domestic market (with growing supply of light high-quality shale oil but continuing demand by US refineries for heavier grades of oil to which they were historically configured) cannot lock domestically produced oil there for long and, as happened with gas, it will be exported. US shale oil resources will continue its move from the right-hand side of the global supply curve to the left-hand side. This move towards the middle will mean that it will not be only the Organisation of Petroleum Exporting Countries (OPEC) crudes that will act as swing producers, but rather both OPEC and, to some extent, US shale oil. Hence, OPEC will remain a swing producer, but US shale oil will influence the market by production volumes and rapid reaction to price fluctuations, though not as a swing producer in precise economic terms.[48]

45 V. Bushuev, A. Konoplyanik and Ya. Mirkin (*supra* n. 42).

46 S. Dale (BP Group chief economist), 'The New Economics of Oil', Society of Business Economists Annual Conference, London, 13.10.2015, p. 14 <www.oxfordenergy.org>.

47 А. Конопляник. Однополярный нефтяной мир – реальная перспектива. – "Экономическая политика: экспертный канал", 5 сентября 2013 г. (A. Konoplyanik, 'Unipolar oil world is the real perspective' Economic policy: expert channel, 5.9.2013) <http://ecpol.ru/2012–04–05–13–45–47/2012–04–05–13–46–05/1016-odnopolyarnyj-neftyanoj-mir-realnaya-perspektiva.html>; A.KONOPLYANIK. 'Energy markets in transition: towards unipolar oil world within double-segment global oil market?', presentation at the Autumn School 'Changing Policies and Cultures in Europe and Russia: Environment, Resources, Energy', jointly conducted by the University of Tartu, Euro College; Freie Universität Berlin, Institute for East European Studies; University of Helsinki, Aleksanteri Institute; 18–24.9.2013, Tartu, Estonia.

48 The debate over whether US shale oil can be considered another swing producer, in addition to OPEC, was recently nicely summarised, in my view, by P. Coy in *Bloomberg Business Week*, who argued that 'OPEC remains the only group that can affect the price of oil by purposely raising or lowering output. US shale producers don't coordinate their actions strategically the way OPEC has in the past; they must take whatever price the market gives them. … They tend to stabilize the market, not add to volatility … What OPEC does still matters. … The US shale industry … it's influential: by contributing to an oil glut, it's kept OPEC from propping up prices. … But a true swing producer has freedom of action. It has a large market share, spare capacity, and very low production costs, and it's capable of acting strategically – alone or in a cartel – to raise and lower production to affect the price. Aramco … fits that description; America's shale producers don't – each is too small to move prices on its own, and they don't act in concert. Also, they have essentially no spare capacity, because they are always producing as much as they profitably can. And their production costs are far higher than those of the Saudis or the Kuwaitis. In the language of economics, US shale oil producers

US shale oil can also compete with conventional oil production from major historical producers like OPEC and Russia due to the changing character of the investment cycle in US shale oil. The new situation is that the short-term economic life-cycle of oil wells and the utilisation of mostly technological rent in oil shale development is markedly different to traditional/conventional oil production, which has a long-term economic life-cycle requiring the utilisation of economies of scale (see figure 4.9).

Table 4.1. Shale and traditional oil: key differences of investment cycles

Parameters	Shale	Traditional
Fixed costs (CAPEX) to total costs	Low	High
Variable costs (OPEX) to total costs	High	Low
Economic life-cycle, years	Short (2–3)	Long (10–15+)
Time lag between FID and 1st oil	Short (weeks)	Long (years)
Responsiveness to oil price fluctuations (short-term price elasticity)	High	Low
Type of rent extracted	Technological rent	Natural resource rent (economy of scale)
Daily production/well decline	High	Low
How this type of investment cycle influence on price volatility	Soften/'shock absorber'* (quick invest effect)	Intensify (delayed invest effect)
Key producers and their financial characteristics	Small and medium independents/ not robust enough (lack of cash to finance from cash flow, fully dependent of debt financing)	Majors/robust (enough cash to finance from cash flow)
Financing (project finance is …)	Conveyer/standardised (each project deal is typical), easy going	Art (each project deal is unique), sophisticated

* Term used of S. Dale
Source: created by author, based, inter alia, on: S. Dale (BP Group chief economist), 'The New Economics of Oil', Society of Business Economists Annual Conference, London, 13 October 2015, p. 7.

are price takers, not price setters.' Coy further cited D. Livingston, who has said that the 'imprecise use of "swing producer" to describe America's shale industry has real-world consequences. People see this language and reflexively accept it. They think that it means the US can balance the oil market. It leads people to think they can turn their backs on the role OPEC plays'. (P. Coy, 'Shale Ain't Got That Swing. OPEC Still Does', *Bloomberg Business Week*, 14–20.12.2015, pp. 13–14). The latter point is very true since we have described earlier the real-world consequences of imprecise use of the terms 'reserves' and 'resources'.

We are witnessing the formation of the new investment-innovative cycle in the global petroleum industry, primarily due to the US shale revolution, which has significantly contributed to the low oil price in 2014–2015, the causes of which differ significantly to the oil price fall in 2008–2009. In both cases we deal with international oil market within the fifth stage of its development as the 'organised' (since the 'Achnacarry Agreement' of 1928) international oil market (according to the classification of Konoplyanik):[49]

– the 2008–2009 oil price fall originated from the financial market, with no oversupply in physical oil. The paper oil market dominates oil price formation in this period (stage) since the prices are formed on the oil financial derivatives market. The oil price fall took place because of oversupply of such derivatives without physical oversupply of oil. Financial oil derivatives were used to balance a decline in the US dollar rate. This is why the market was overheated and the inflated financial bubble burst. The outflow of cash from the global financial market, including from the paper oil market (i.e. from the market of oil-related financial derivatives), as a result of the mortgage crisis in the US, created oversupply of paper oil (of oil-related financial derivatives), and thus the price for paper oil went down and was imported on the physical oil market.[50] Long-term, capital-intensive (and thus very inert due to the nature of its investment cycle) conventional physical oil was not immediately affected by this price fluctuation due to its low short-term price elasticity (see figure 4.9), and the US shale oil had not yet affected the global oil market at that time. A lack of liquidity on the paper oil market after the crisis was quickly met by three consecutive quantitative easing programmes implemented in the US. This is why in 2009 the paper oil price took off again (immediately imported on the physical oil market) and the prices then stayed at their pre-crisis levels of around 100–110 USD/barrel for another half-decade, balancing the continued weakening of the US dollar;
– On the other hand, the 2014–2015 oil price fall did not originate in the financial market (due to oversupply of oil-related financial derivatives), but rather from oversupply on the physical oil market. Two major explanations for this current fall are: (a) macroeconomic cycles (the regular super-cycle

[49] Although for the 2014–2015 oil price decline it is not yet clear to me whether it is still the late fifth, or the early-sixth period. For classification of the periods see A. Konoplyanik, 'Evolution of contractual structure of the world oil market', in V. Bushuev, A. Konoplyanik and Ya. Mirkin, *supra* n. 40, Chapter 2, pp. 80–190 (см. А.Конопляник. Глава 2: Эволюция контрактной структуры на мировом рынке нефти, с.80–190. – в кн: Бушуев В.В., Конопляник А.А., Миркин Я.М. и др. Цены на нефть: анализ, тенденции, прогноз. – М:, ИД "Энергия", 2013, 344 стр.); 'Global Oil Market Developments and Their Consequences for Russia' *The World Financial Review*, November-December 2013, pp. 49–53 <www.worldfinancialreview.com>, etc.

[50] Ibid., see also: A. Konoplyanik, *supra* n. 42.

of mineral resource and of fluctuations in the US dollar: a strong US dollar means low prices for oil and other mineral resources, and vice versa);[51] and (b) a totally new noticeable investment cycle in oil has brought another swing supplier in the global oil industry (in addition to traditional one, namely Saudi Arabia) to the fore, namely US shale oil.

The paper oil market continues to be the key to oil price formation, but it reflects the realities of the physical oil market where oversupply took place. What has also changed is the nature of incremental supply in physical oil: now it is not only OPEC oil fields which monetise the *economy of scale* effect related to development of their conventional oil fields, but also US shale oil resources which monetise *technological rent* for shale oil development.

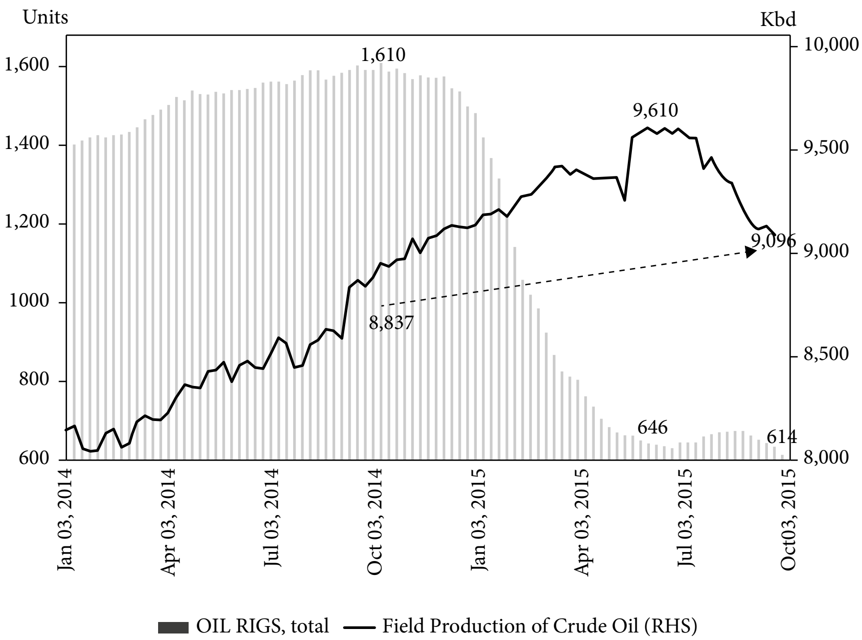
There are few major differences between the traditional investment (innovative and investment) cycle in conventional oil from the analogous one of shale deposits (both shale oil and shale gas) (see figure 4.9).

Firstly, the economic life-cycle of shale development (investment cycle of shale wells) is much shorter than in conventional oil, since the production curve in shale is much shorter and the fall in shale production is much more radical (in first one to two years shale oil well output can fall five- to sixfold, to 15–20% of the initial production levels)[52] compared to conventional oil development. This is why the intensity of drilling (number of wells) in shale oil is much higher than in conventional oil, thus requiring higher production levels to be able to pay back the costs. The US economic model (its 'above-the-ground' characteristics) have once again converted this negative into a positive: the shorter economic life-cycle of shale projects has provided opportunities to introduce innovations quicker than in conventional oil production. The US economy's high adaptability to innovation, plus demand for intensive new drilling, make the learning curve in US shale much steeper, thereby providing opportunities to implement innovations within shorter periods/life-cycle.

51 This macroeconomic analysis is presented in the works, inter alia, of Russian financier and economist Dr (Econ.) Prof. Yakov Mirkin, Head of the Board of Director of Investment Company Eurofinance and Head of Capital Markets Department, IMEMO RAS <https://ru-ru.facebook.com/yamirkin>; <www.eufn.ru/; www.mirkin.ru/; https://twitter.com/EUROFINANCY>.

52 According to Rystad Energy, at Oasis Petroleum's West Williston acreage in Bakken, the first-year shale production decline is 85% (Rystad Energy, NASAnalysis product presentation, personal communication provided to the author).

Figure 4.9. US oil output had been declining since early July, yet still was 260 kbd higher y-o-y in end-September



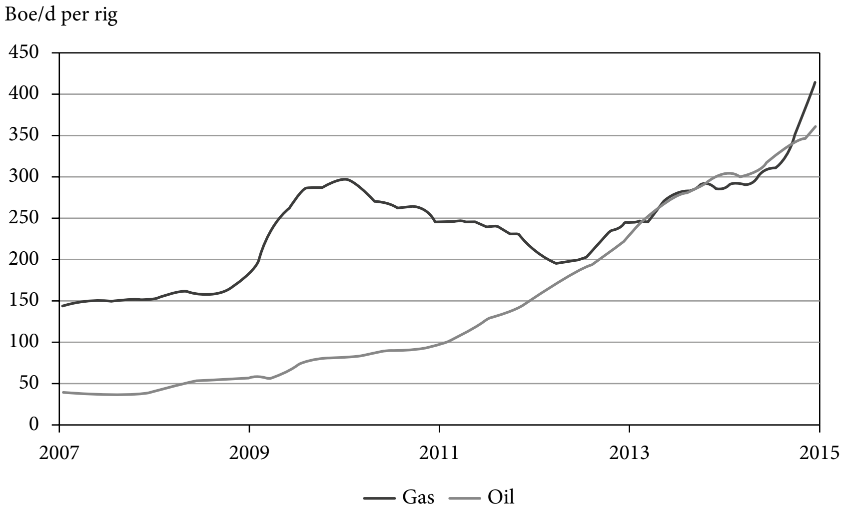
Source: V. Drebentsov, Oil Market Update, October 2015, IMEMO Workshop, Presentation at the seminar 'Low world oil prices and its consequences for macro-economy and oil sector of Russia' within Forum IMEMO-BP 'Oil & Gas Dialogue', Moscow, IMEMO RAS, 21.10.2015, slide 7, http://imemo.ru/files/File/ru/conf/2015/21102015/21102015_PRZ_DRE.pdf.

A good example of this is illustrated in figures 4.10 and 4.11 below, taken from the presentation of Vladimir Drebentsov,[53] Chief Economist of BP Russia. Despite an almost threefold decline in the number of active drilling rigs in the US from October 2014 to October 2015, oil production in the US in the same period grew by 3% (see figure 4.10). This means that the productivity of oil wells has increased. This trend is also seen in the long term, where new US well production per rig has increased sevenfold for oil and almost threefold for gas in the period 2007–2015 (see figure 4.11).[54]

53 V. Drebentsov, presentation at 'Oil & Gas Dialogue' Seminar, 21.10.2015, jointly organised by BP and IMEMO RAS <http://imemo.ru/files/File/ru/conf/2015/21102015/21102015_PRZ_DRE.pdf>.

54 According to an example from NASWellData (Rystad Energy), the 'learning curve' for the Marcellus shale play has increased average new well productivity sixfold between May 2009 and August 2012 (a generalised trend) (Rystad Energy, NASAnalysis product presentation, personal communication provided to the author).

Figure 4.10. US new-well production per rig



Source: V. Drebentsov. Oil Market Update, October 2015. IMEMO Workshop, Presentation at the seminar 'Low world oil prices and its consequences for macro-economy and oil sector of Russia' within Forum IMEMO-BP 'Oil & Gas Dialogue', Moscow, IMEMO RAS, 21.10.2015, slide 8, http://imemo.ru/files/File/ru/conf/2015/21102015/21102015_PRZ_DRE.pdf.

Thus, despite the oversupply of US hydrocarbons to the markets (first in gas, then in oil, both due to US shale development), shale producers have correspondingly diminished their costs, thus supporting competitiveness. Pareto's law, that 20% of producers provide 80% of output, is illustrated in shale oil/gas production in the US as well.[55] This provided US shale oil producers with the opportunity to compete with Saudi Arabia for a share in the international physical oil market (reflecting the new type of competition: economy of scale versus technological

55 Regarding North America's shale production, Rystad Energy warn not to 'expect a significant reduction in NA shale production growth at current low oil prices', because their calculations show that, based on October 2014 levels of oil shale production of 6,300 kboe/d (thousand barrels of oil equivalent per day), the production range of 5,700–6,600 kboe/d can be supported within a year with a breakeven Brent oil price range of 50–60 USD/bbl; a price of 40–50 USD/bbl can support 4,700–5,700 kboe/d; 30–40 USD/bbl 4,400–4,700 kboe/d; 20–30 USD/bbl4,300–4,400 kboe/d; and even 10–20 USD/bbl 4,100–4,300 kboe/d. On the contrary, if the Brent oil price were to rise to 60–70 USD/bbl, within a year this would have increased US shale oil production from October 2014 levels to 6,600–7,100 kboe/d; if the price were to rise to 70–80 USD/bbl, then production would increase to 7,100–7,500 kboe/d; if to 80–90 USD/bbl, then to 7,500–7,600 kboe/d; and if to 90–100 USD/bbl, then to 7.600–7.700 kboe/d. If the Brent oil price were to rise above 100 USD/bbl, then it would have increased US shale oil production to 7,700–8,100 kboe/d (B. Villanueva-Triana (Shale Analyst), 'Impact of North American Shale Development', presentation at the Unconventional Oil & EOR Russia Conference, 3.12.2014, Moscow, slide 7).

rent). However, it is important to note that swing producers (OPEC and US shale gas producers) are obliged to continue oil production under any price:

– for the OPEC producers this is because the current oil price is well below their 'zero budget deficit oil prices'. There is also a need to support budgetary spending programmes by supporting/protecting their market share and utilising (taking money back from their) sovereign fund investments in financial instruments;
– for US shale oil/gas producers this is because they have been developing their fields mostly based on project (debt) financing, and thus they must at least service their debt in order not to became bankrupt, meaning that the financial bubble will gently deflate, but will not burst. Inevitable bankruptcies of shale companies will result in the traditional redistribution of property rights (ownership of assets).[56]

High adaptability and readiness to quickly react to price fluctuations reflect the current situation where a lot of wells have already been drilled, but multiple fracking on them has not yet been implemented (known as frack-lock). This means that when prices rise, fracking at these wells will be done immediately, thereby increasing output with minimal cost, since most of the well costs have already occurred, enabling increased production at low incremental costs.

Rystad Energy[57] notes that North American shale production is changing the global oil supply trends. According to Rystad's estimate, US shale liquids output in 2020 is expected to reach 12.0 million barrels per day (MMbbl/d) (sourced from the following fields: Permian, 3.0 MMbbl/d; Eagle Ford, 2.9; Bakken, 1.7; Niobrara, 0.7; others, 3.7) compared with the outlook for some other countries for 2020 liquids: Saudi Arabia, 10.4 MMbbl/d; Russia, 10.4; UAE, 3.7; Kuwait, 2.6; Venezuela, 2.7; Nigeria, 2.2; Libya, 1.0.[58] This makes shale production a true game changer.

56 Of course, some shale-oil/gas-producing companies have not managed to stay competitive in the low-price environment. In January 2015 US company WBH Energy, a shale gas/oil producer outside of the top 15 net shale producers, announced bankruptcy as a result of the ongoing oil price decline. The company's debt in recent months up to that announcement had increased to 50 million USD <www.utro.ru/news/2015/01/09/1228784.shtml>. Anglo-Australian company BHP Billiton stated in July 2015 that it was writing off 2 billion USD of its oil business in the US due to the fact that, firstly, its shale oil development project Haukville in southern Texas happened to be more technically complex from geological viewpoint and thus more costly than was planned earlier. Secondly, in 2011 BHP Bulliton acquired US shale gas producer Petrohawk. This purchase seemed attractive at that time, though it cost BHP 12 billion USD, including 3 billion USD of Petrohawk's debts. But soon BHP was to write off 2.84 billion USD since US gas prices has fallen ('Компания' (*Company* magazine), 21.7.2015). Prof. F. William Engdahl from Princeton University wrote in August 2015 that 'when the oil price fell to 53 USD/barrel FRS had to buy-back the debts of US shale oil companies from other banks in the hope to prevent the panic', 8.8.2015 <http://ria.ru/world/20150808/1172736525.html#ixzz3iLz3e3ux>.

57 An independent oil and gas consulting services and business intelligence firm and one of the key analytical companies for US shale development.

58 B. Villanueva-Triana *supra* n. 56, slide 10.

– The *tenth* effect has been on the global capital market. Gas price cuts in the US have led to a reverse of international capital flows. Attracted by low energy costs, investments in energy intensive industries are starting to return to the US from developing countries, which were previously more attractive because of low labour costs and lower environmental standards after the price rise in the 1970s.

The US shale revolution is a real game changer with far-reaching global consequences, especially if we take into account the role of the US in the world economy. The transformations caused by the shale revolution can be described in terms of 'domino', 'matrix' or 'economy of scale' effects. The consequences are irreversible, with the point of no return having already been passed. Although the American shale revolution has already played its historical role, it raises one last question: what is the future of shale production in the US?

5. CURRENT US PROBLEMS: FINANCIAL PRICE TO PAY FOR SHALE REVOLUTION

As pointed out earlier, one of the most important factors in the American shale revolution was the availability of affordable credit in the pre-financial crisis period, which was indispensable for the intensive project (debt) financing of shale gas development. However, at present, when gas prices are falling as a result of excess supply, this has led to the growth of a financial debt bubble. In one article from 2012, significantly entitled 'The Revolution will eat its children', it was noted that 'even before the gas price crash shale gas producers were spending two to five times their operating cash flow to fund land purchase or leases, drilling and completion programs'.[59] The same conclusion was made in a *Financial Times* article in late spring of the same year.[60]

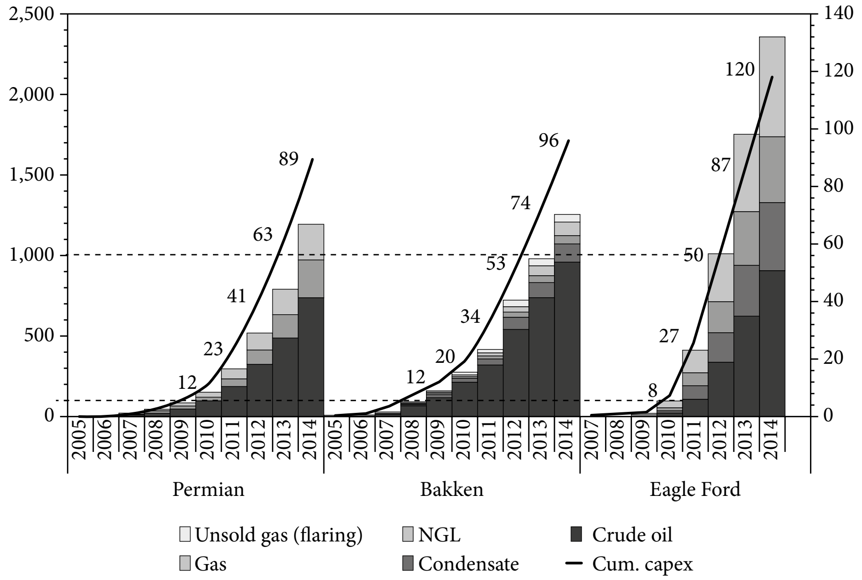
The shale gas production curve (a dramatic decrease of well yields in the first one to two years) requires escalated drilling and increased expenditure, which is accompanied by growing costs of debt servicing. According to Rystad Energy, shale production is directly proportional to spending but the ratio varies per play (see figure 4.12, related to three key plays which provided two thirds of US liquids production in 2014). And as this figure illustrates, most of the production increase in recent years was related to liquids: crude oil, condensate, and NGL (natural gas liquids). The Shale Peer Group (15 key shale companies, making up to about 40% of shale activity) has relied on borrowing and the sale of assets to fund investments: the breakdown of reported cash flows shows that this shale peer group has invested more than it has generated from operations. Cash flows from operations (defined as revenue minus operating expenditure minus taxes)

[59] 'United States: The Revolution Will Eat Its Children' (2012) *Shale Gas Investment Guide/Poland* 87–88.

[60] J. Dizard, 'Familiar echoes in shale gas boom', *Financial Times*, 6.5.**2012.**

have been balanced through a combination of sales of assets, net borrowing and equity issuance.[61]

Figure 4.11. Shale production is directly proportional to spending but the ratio varies per play

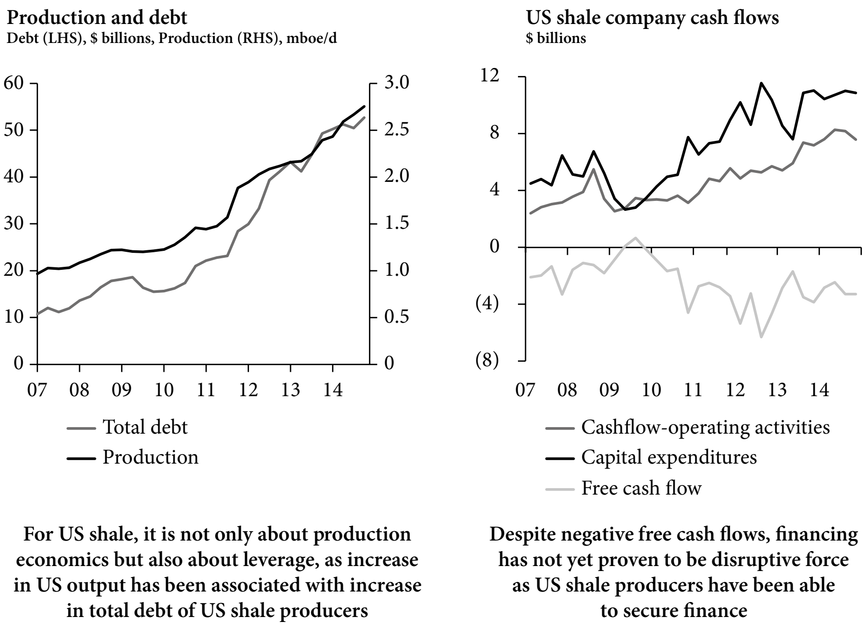


Source: B. Villanueva-Triana (Shale Analyst, Rystad Energy), Impact of North American Shale Development. Presentation – Extract and Unconventional Oil & EOR Russia Conference, 3 December 2014, Moscow, slide 11.

The same conclusion came from Prof. Jonathan Stern and Bassam Fattouh who rightly posited that 'US shale is not only about production economics but also ability to raise debt' (see figure 4.13).[62] Despite negative free cash flows, financing has not yet proven to be a disruptive force, since US shale producers have continued to secure finance. One of the reasons for this is that US shale is a unique example of cost reduction in the oil and gas sector: the Oxford Institute for Energy Studies (OIES) estimates that extraction costs (producer price index) in early 2015 remained at 60% of the December 2012 level.[63] According to Stern and Fattouh (concurring with the view of Rystad Energy and the views of this author), 'US shale has proven to be more resilient than originally expected with efficiency improvements and lower costs of services bringing down the break-even cost.'[64]

61 B. Villanueva-Triana *supra* n. 56, slide 14.
62 J. Stern and B. Fattouh, 'Lower Oil and Gas Prices: new phenomenon or history repeated?', presentation at the 'ENERGETIKA-XXI', St. Petersburg, 12.11.2015, slide 14.
63 Ibid.
64 Ibid.

Figure 4.12. US shale is not only about production economics but also ability to raise debt (OIES)

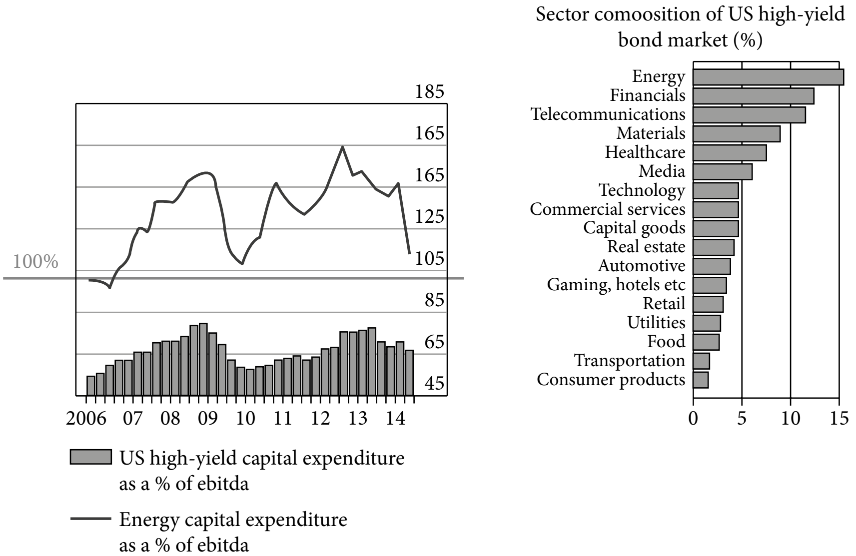


Source: J. Stern and B. Fattouh, Oxford Institute for Energy Studies, 'Lower Oil and Gas Prices: new phenomenon or history repeated?' Presentation at the ENERGETIKA-XXI, St. Petersburg, 12 November 2015, slide 18.

After the 2009 crisis and gas price decline, debt servicing became more costly. This has resulted in a debt pyramid and a growing bubble of accumulated debt, which affects companies differently. As previously mentioned, a rapid decline of shale wells debits requires intensive drilling, which creates additional problems for small and medium-sized companies (which form the majority of shale oil and gas producers). Small and medium-sized companies are not financially robust, lacking cash to finance from cash flow, and are fully dependent on project (debt) financing (see figure 4.13). The situation is different for vertically-integrated majors, who are robust enough to finance from cash flow (see figure 4.9). On the one hand, this presents a positive challenge since project financing, which has been viewed as an 'art for the financial aristocracy' (making the case for mega-projects utilising an 'economy of scale' approach), has been methodically transformed into a standardised (or conveyer-type) financial technology of raising debt capital (see figure 4.9). But the dark side of this is that the debt of these companies is growing, and due to the worsening price environment (low gas and oil prices) the bulk of debt capital (new borrowings) has moved to the junk bond market (to borrowing with credit ratings below the 'investment grades' zone).

As presented in the *Financial Times*, and based on Deutsche Bank research data,[65] 'energy companies have been borrowing to fuel growth … making energy debt the biggest component of US junk bond market.' Such debt exceeded 15% at the end of 2014. Energy capital expenditure as a percentage of earnings before tax, interest, depreciation and amortisation (EBITDA) has fluctuated above 100% since the mid-2000s, and US high-yield capital expenditure as a percentage of EBITDA has fluctuated around 60–80% (see figure 4.14).

Figure 4.13. Energy companies have been borrowing to fuel growth … making energy debt the biggest component of the US junk bond market



Source: T. Alloway, 'Crude slide sparks oil-related debt fears', *Financial Times*, 22/23.11.2014, p. 15.

This has changed the financial market's perceptions in relation to hedging of today's financial risks, and has led the market to question whether US shale producers will be able to pay back their production costs because of the low oil and gas prices on the domestic market. The hedging facilities available can only postpone, but not resolve, the problem. A solution to this was expected with the US entry into the LNG Asia-Pacific market, where a premium gas price after the Fukushima accident would have been able to start to reduce the debt bubble and gradually reduce the risk of its collapse. The US system of subsoil use requires that non-developed licensing acreages be quickly returned to the land owners; therefore, the leaseholders cannot afford to postpone their development.

65 T. Alloway, 'Crude slide sparks oil-related debt fears' *Financial Times*, 22/23.11.2014, p. 15.

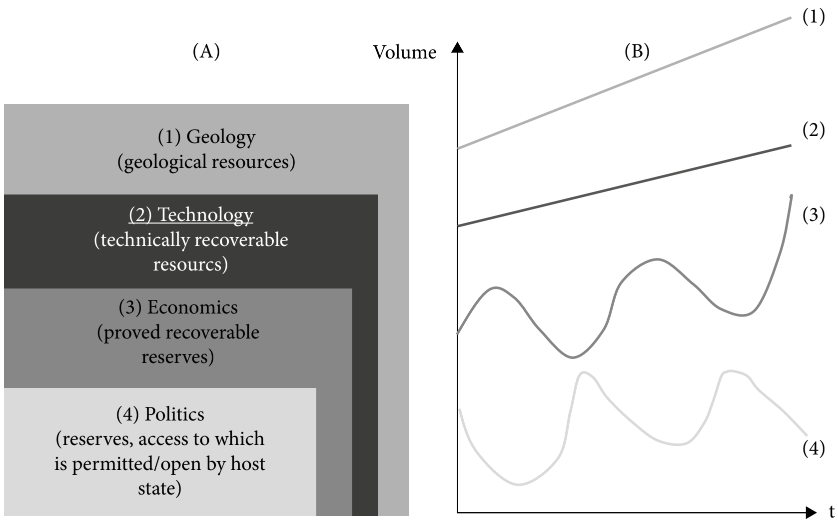
The 'second wave' shale producers (who entered the market in the wake of successes of the first wave) were faced (prior to end-2014 oil price collapse) by the late land lease dilemma (which is expensive, attracting a premium): either return the land to the owners (and write off the losses) or alternatively continue drilling (with lower losses) in expectation of LNG export approvals in order to sell to the Asia-Pacific market and receive a high premium LNG price to pay back accumulated project financing debt which has been used to develop shale plays (with already high accumulated interest). However, the recent oil price collapse has downgraded the usually high-priced, oil-indexed LNG on the Asia-Pacific market. As a consequence, US shale economics based on hedging of current negative cash flows requires re-evaluation.

Shale producers also fear that the US government may curtail the tax breaks for independent companies which deduct drilling costs from their tax declaration, enabling the funding of new drilling while staving off bubble growth. Many companies accept writing off the losses in the US in the hope of exporting their experience to the shale markets of other countries. But the global oil price decline has further slowed down limited shale prospects outside the US, as compared to the scale of US shale gas revolution. Thus the nation that secured the shale revolution and triggered the chain reaction of its global consequences is faced with the task of preventing a collapse that is caused by the shale producers' financial debt bubble. Time will show whether this can be achieved; however, the high level of debt with junk credit ratings held by US shale producers is the major issue at this stage of US shale gas development.

BOX 1: RESOURCES VS RESERVES: GEOLOGY, TECHNOLOGY, ECONOMICS, POLITICS

There are four stages of assessment of natural resource potential, from theoretical (conceptual, speculative) to extremely economic under the 'matryoska' principle when one resource category is a part (thus located, inserted inside) of the other (see figure 4.15). The assessment is made taking into account a combination of factors: (1) geological, (2) technological, (3) economical, and (4) political (figures in brackets refer to the same figures at figure 4.15). The correct use of terminology for each of these categories for non-renewable energy resources defines the comparative size of quantitative assessment of the resource category in question. Two first categories refer to 'resources', the latter two to 'reserves'.

Figure 4.14. Resources vs reserves: geology, technology, economics, politics



Source: compiled by author.

Geological assessment of non-renewable energy resources (in-situ resources) is based on our knowledge of its genesis and of the subsoil, regardless of current capacity to extract the resource potential. Such resource assessments for all energy resources has an adjusted growing trend within the time-frame.

Technically recoverable resources are those geological resources which it is potentially possible to extract with the help of existing/known technologies, regardless of whether these technologies are proven or still at the RD&D stage, whether their large-scale use is possible (manufacturing is available), and if so, whether they are affordable (commercialised), and what will be the price of the end-use energy (at the consumer end) if/when produced with such primary energy production technology and then delivered to the end-user through the rest of the energy value chain. For immediate practical business use such resource estimates does not have direct economic effect, non-dependent on whether it is not yet known whether such technologies will prove profitable, or if it is already known that they are still unprofitable. This resource estimates are for future economic development/activities. Nevertheless, such estimates are frequently called 'technically recoverable *reserves*' Which creates perception of their immediate importance for business purposes. Quantitative assessment of this resource category has aa adjusted upcoming trend within the time-frame.

Proved recoverable reserves (PRR) are those technically recoverable resources which it is profitable to develop under current market conditions with available technologies. Today's market prices, at least for hydrocarbons, are very volatile as a result of both cyclical (fundamental) and current (state of the market) changes. Such high volatility has been inherent in these markets since their commoditisation (in the 1980s 1990s) and later financialisation (in the 2000s), and since physical energy markets became secondary to paper energy markets (markets of energy-related financial derivatives) as a result of these changes. This is why PRR estimates can (and indeed need to) fluctuate in line with oil price fluctuations. Thus, unlike non-economic categories of energy resources, they do not have linear growing trend within the time frame as 'geological' (knowledge-based) and/or 'technical' (technology-based) resource categories. When the oil price rises, the price of PRR goes up, and vice versa (see figure 4.15).

Not all PRR within one single country are accessible for exploration and production (E&P). Each sovereign state has its sovereign right (protected by multilateral international 'soft' and 'hard' law related to states' permanent sovereignty over their energy resources) to decide whether or not to open their national onshore/offshore areas for E&P. The level of openness depends on the licensing policy implemented in the state, which might impose a number of limitations. Usually, the lower the energy market prices, the more states tend towards opening/easing access to their energy resources (liberalisation of subsoil regime) and vice versa, when the energy prices go up, more resource-owning countries tend to implement what is sometimes called 'resource nationalism', including limitation of access to domestic natural resources. This is why accessible levels of PRR in the individual state might change in an inverse relationship to the price trends in the given energy market (see figure 4.15).

This is why it is inappropriate to assess, say, an EU Member State's prospects of reducing its current energy dependence on it current import energy supplies (say of Russian gas), on the basis of the technically recoverable unconventional resources in that country (if they are not yet domestically commercialised on a large scale). This has led to the over-estimation of their importance from an economic viewpoint (while presenting resources estimates instead of reserves) and thus created misperceptions and over-expectations that fail to take into account the time and money required to achieve the stated aim of 'energy independence'.

BOX 2: INTERPRETATION OF CONVENTIONAL VERSUS UNCONVENTIONAL ENERGY RESOURCES AND 'HUBBERT'S CURVES'

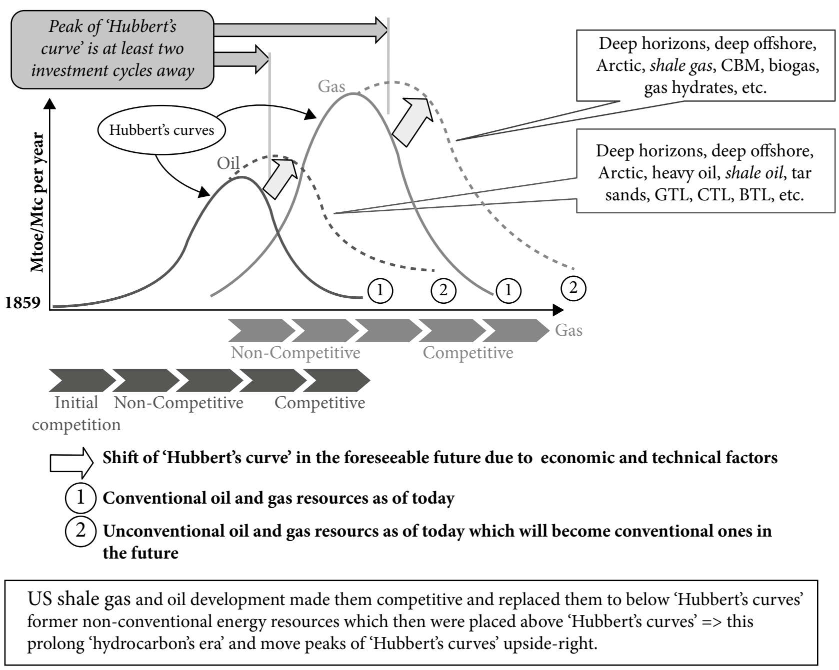
There is no universal understanding today regarding what to consider as 'non-conventional' energy or hydrocarbon resources. It seems that the key approach to classification is a geological one, taking into consideration different geological parameters/characteristics of that natural resource. But if we look at this problem from economic viewpoint, then there should be a dividing line of a different sort: whether it is profitable or not to develop the resource using the given/available technologies non-dependent on how this or that energy/hydrocarbon resource is treated (called, classified) from a geological viewpoint. Hence, we can consider to be non-conventional energy/hydrocarbon resources all those categories of utilisation of net energy (useful energy) from natural sources which are either not yet technically well developed (i.e. still at the R&D stage), or not yet developed to be economical/profitable in the given state of the market conditions (not yet commercialised).

This means that 'non-conventional' (in an economic interpretation of this term) energy resources are located outside of the so-called 'Hubbert's curve'. Only available, commercialised (profitable, economically justified) developments transfer these resources from outside to inside Hubbert's curve and thus mean that they are 'conventional' resources. Thus the space inside Hubbert's curve expands. This, in turn, increases the level of self-sufficiency for the given energy resource, whether it is a liquid, gaseous or solid resource (see figure 4.16).

Each technological breakthrough (revolutionary technological advance) and its further commercialisation in the area of energy production or energy efficiency prolongs the era (life-cycle) of non-renewable energy resources (liquid, gaseous, solid) and moves towards the upper-right Hubbert's curve. Thus the technological breakthrough in shale development in the US (a combination of 3D-seismic, horizontal and directional drilling, and multiple fracking) has made it economically competitive. This breakthrough has moved geological categories of these energy resources which were earlier considered non-economic (and thus non-conventional and outside 'Hubbert's curve') to now fall within Hubbert's curve.

PROEF 2

Figure 4.15. Author's economic interpretation of Hubbert's curves and US shale revolution



Primary source (basic figure *): A. Konoplyanik, 'Energy Security and the Development of International Markets' in B. Barton, C. Redgwell, A. Ronne and D.N. Zillman (eds.), Energy Security: Managing Risk in a Dynamic Legal and Regulatory Environment. (International Bar Association / Oxford University Press 2004), p. 49.
* Later reproduced in 'Putting a Price on Energy' (ECS 2007), p. 53, where this particular figure is taken from and further upgraded.

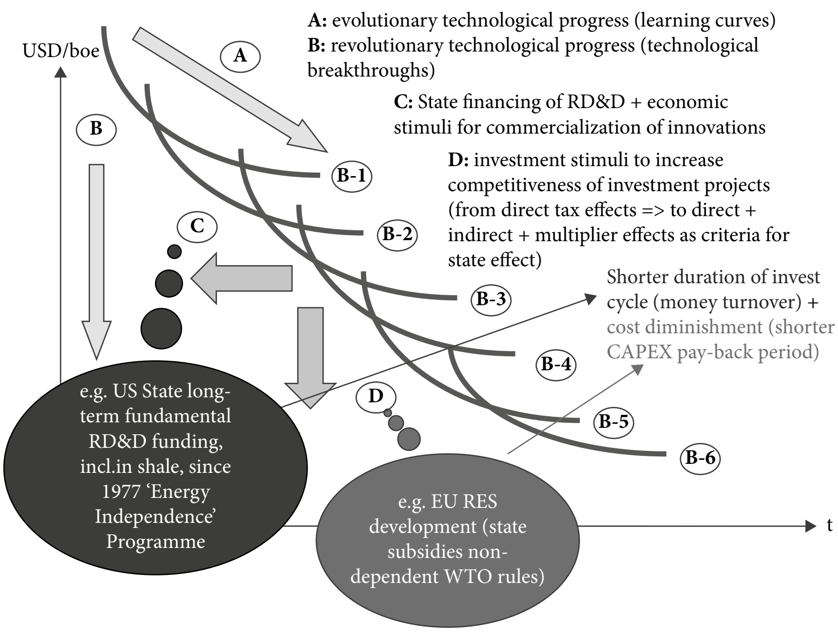
Regardless of international division of labour and international trade and investment cooperation, in the individual given state energy resources can be considered as non-conventional (though they can in other state(s) be considered technologically and commercially well developed and thus conventional) since they have not yet been developed in this given state due to the combination of internal and/or external factors. Domestic energy resources might not have reached the stage of advanced technological development and thus the level of their commercialization in result of:

– technological and/or financial restrictions on international movements of goods, services or capital (as for instance in Russia today, where, as a result of Western sanctions, financial and technological restrictions have since 2014 been placed on technologies for deep offshore oil and gas development (including the Arctic offshore), on shale development, etc.) (external factors);

– investor-unfriendly policies and their investment or even prohibitive tax and investment policy, over-bureaucratised administrative and/or regulatory (licensing) procedures and other (commercial and non-commercial) risks within this state (internal factors).

On the other hand, the state can effectively help its national business to transfer non-conventional energy resources into conventional ones more quickly and to increase their competitiveness. State support for RD&D improves 'learning curves' for new revolutionary advances (breakthroughs). Consequent investment stimuli at the commercialisation stage affects the whole 'learning curve' for the new technological approach (see figure 4.17).

Figure 4.16. 'Learning curves' and the role of state



Source: compiled by author.

Figures 4.5–4.7 above demonstrate how this was practically done in the USA in regard to unconventional gas resources, including shale gas, in other words, how the US government has created the prerequisites of 'US shale gas revolution' and its practical implementation in the US.