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Brexit and UK Energy Security: Perspectives from Unconventional Gas Investment and the Effects of Shale Gas on UK Energy Prices

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Abstract: Many aspects of the present and future effects on the UK economy, industry, and households, of Brexit have been researched. One thing which appears certain about Brexit is the shadow of uncertainty it casts on the future of business in the UK and its telling effects on the UK economy. It is believed that Brexit has negatively affected the level of investments in the UK, including investments in energy and crucially the upstream oil and gas, with the UK North Sea being starved of investments since 2014, leading already to increased energy bills. The UK is a net importer of natural gas—a major source of its energy, with some dependence on supplies from interconnectors from Europe. At the same time, UK energy companies participate in the common energy market which enables them to undertake arbitrage trading under the common market rules. However, both of these benefits could be lost under a Brexit scenario where the UK and EU come to a no-deal or hard border arrangement. Meanwhile, domestic production of energy in the UK has declined for nearly two decades now and import bills for natural gas are growing—they were £14.2 billion in 2017; £11.7 billion in 2016 and £13.4 billion in 2015—with Government projections indicating an upward trajectory for natural gas imports. It is however believed that the UK has great potential to exploit shale gas to her advantage in order to reduce her reliance on foreign energy which is: (1) less predictable in terms of supply and price affordability and (2) dependent on exchange rates—a primary means through which energy prices increased in 2016/17 post-Brexit referendum vote. The current study extends discussions on shale gas to cover a review of the potential of natural gas from shale formations to cushion UK households against further erratic gas prices due to Brexit and also assesses the potential effects Brexit may have had on the level of investments in shale gas, in order to suggest policy options for government consideration. Contrary to popular studies, we find evidence to suggest that shale gas has the potential to reduce energy prices for UK businesses and households at commercial extractions, under both hard and soft Brexit scenarios, but with more benefits under hard Brexit. Importantly, we find that from 2008 to 2017, average UK net export of natural gas was 5,191 GWh per year to the EU. We also find and argue that Brexit may have starved the nascent fracking industry of investments in a similar way it did to investments in conventional oil and gas and could have increased investor risk premium for shale gas development, the ultimate effect of which was a categorisation of fracking (company stock) as riskier asset for investors on the London Stock Exchange. We recommend that shale gas development be expedited to maximise its benefits to UK energy consumers post-Brexit or economic benefits from the resource could be diminished by rising operator costs due to delays and effects of the public's perceived negative opinion of the method of extraction.

Keywords: shale gas; development; investment; Brexit; energy prices

1. Introduction

Brexit holds enormous uncertainty for the future of most businesses in the UK. Various assessments have been made with regard to the implications of Brexit. It has been found to have plunged bank stock prices [1], negatively affected leisure and travel [2] and, reduced investments [3] among others. Perhaps a more crucial assessment of the potential implications of Brexit for UK households and businesses is in the area of energy supply and security. The UKCS produces and supplies the largest share of domestic energy to UK homes and businesses. However, according to the Oil and Gas UK, Brexit could cause "production shut down of the UK North Sea" under a hard or no-deal Brexit scenario. The question then is, under such scenario, might shale gas contribute to the security of UK energy supply? Energy is a fundamental propeller of economic activity and continued investment in its development is as necessary as society's incessant requirement for it. It has been reported by Oil and Gas UK that investments in oil and gas in the UK have fallen 50% over the last five years [4]. Certainly, such a dilemma warrants research into the potential of alternative energy sources, including the recently discovered shale gas and an assessment of the extent of any potential Brexit effects on its investments.

The UK is a net importer of energy, incurring a net import bill of £14.2 billion in 2017; £11.7 billion in 2016 and £13.4 billion in 2015 [5]. Consequently, the Government now favours cheaper "home-grown" energy, and since 2008 has issued licenses and offered blocks in two Onshore Licensing Rounds [6,7] (UKOOG 2013, OGA 2015), to companies to explore the potential of shale gas—an unconventional natural gas by hydraulic fracturing. In anticipation, a UK Parliament document records that "indigenous shale gas could provide, in the medium term, an additional source of supply which combined with policy changes to encourage investment in generating capacity, could help ensure that competitively priced electricity supplies are maintained at an adequate level for many years to come" [8]. In Andrea Leadsom's speech on shale gas in 2016 (which was published by DECC), the former Conservative Party Minister of State for Energy stated that "shale is a fantastic opportunity for the UK", adding it will be a transition fuel into a greener future, enable decarbonisation from coal consumption, strengthen the UK's energy security and provide jobs and financial security for families and tax revenues for the government [9]. The Minister added, "Unlocking the shale gas deep underground is too big an opportunity to pass up" (ibid). Yet, to unlock the opportunity requires investment by industry at a time when Brexit presents significant uncertainties for businesses and investment in the UK.

Unconventional oil and gas developments hold significant geological uncertainty and shale gas in particular has a slower pace for recovering investment [10]. Developing shale gas in the UK thus implies exposure to geological and commercial risks, including potential political risks inherent in Brexit, but to what extent does Brexit impact the development (investments in) of shale gas? At the back of this reality and the enormous government optimism lies questions as to whether shale gas indeed presents as much opportunities as anticipated by the Conservative Government. Stevens [11] in his paper on the "hype" and "reality" of shale gas revolution believes there are enormous uncertainties that the shale gas revolution itself presents to investments in shale and natural gas in general and argues the benefits of shale gas have been hyped. Furthermore, the author argues that UK shale gas may not lead to reduced gas prices to UK households [12]. May these issues justify non-development of shale gas in the UK?

The UK shale gas industry is relatively new but has met and continues to face significant opposition from environmentalist groups and many lawsuits [13–16], and unbalanced media publication that fuel public opposition against fracking [17]. Perhaps an even more excruciating challenge might be the possible negative implications of Brexit that could threaten the benefits of energy security and other anticipated significant benefits for which government and industry remain resolute to the course of shale gas exploitation. On the other hand, whether Brexit presents newer and additional benefits to shale gas development for the UK, remains unknown although such information would guide policy discourse and Brexit negotiation. The current research contributes to the literature

and discourse on UK shale gas in two ways. First, a review of the potential impacts of Brexit on shale gas investments and energy price is presented. Then, second, an assessment of the effects of UK-produced shale gas on domestic energy price is presented. The research does not attempt to predict the potential effects of Brexit on fracking in the UK. It does not also attempt to review or predict the UK's energy trade agreements post-Brexit.

The rest of the paper is organised as follows: in Section 2.1, a brief background is provided to Brexit. Section 2.2 reviews the effects of Brexit on shale gas investment, whereas Section 2.3 presents potential implications of Brexit for the regulation fracking in the UK. In Section 3, we review the UK energy security situation in Section 3.1. Post-Brexit, tariff and non-tariff barriers could apply to trade between the UK and EU and indeed third countries. Section 3.2 therefore analyses some potential issues relating to trade protectionism. In Section 4, we present the potential of commercial shale gas production for UK energy supply in Section 4.1. Importantly, Section 4.2 presents scenarios and evidences of the potential moderating effects of commercial shale gas production on gas price under hard and soft Brexit scenarios. Following, evidences and analysis of the relative trade positions of the EU and UK on natural gas via interconnection are presented along with an evaluation of the potential impact on UK gas supply and price in Section 4.3. Section 4.4 reviews the impact of Brexit on wholesale and retail energy prices, whilst Section 5 concludes the research with some recommendations.

2. Brexit and Shale Gas Investment

2.1. Brexit: Background and Definitions

On the 23rd of June 2016 the United Kingdom voted to exit the European Union (EU) in a general referendum where 52% of British voters supported the exit from the EU. This event is now popularly referred to as "Brexit". To proceed with the withdrawal process, the UK invoked Article 50 of the EU Lisbon Treaty on 29th March 2017 giving the UK a two-year period to negotiate. As it stands, the UK is expected to exit the EU at 11 pm UK time on Friday 29th March 2019 although, with the agreement of the member states, the date can be extended.

The exit of a member state is unprecedented in the history of the EU and therefore Brexit came with significant uncertainties causing an initial financial maelstrom that left the Pound Sterling loosing value against major global currencies. Also, the uncertainties caused a slowdown of the economic growth and productivity of the UK [18]. The exit negotiation is currently ongoing, and it remains uncertain whether or not a deal will be reached by March 2019.

2.2. Effects of Brexit on Investment in Shale Gas

The UK North Sea has been struggling to attract new investments since peaking in 1999 and 2001 for oil and gas production respectively, yet from 2004 as in Figure 1, the oil and gas industry was making modest but steady growth in investments until 2014, when investments took a steep decline. Obvious responsible factors include the matured nature of the basin and increasing costs typical of mature basins, and the falling crude oil price in 2014, which led to the postponement and cancellation of capital projects by most E&P companies [19–21]. Nonetheless, analysing investments in the entire energy industry reveals there are more responsible factors, potentially political, and chief of which is Brexit and its attendant uncertainty. In 2017, investments in the energy industries grew at just 0.6% overall, with most of this in electricity at 60%; 30% in oil and gas extraction; 7.5% in gas and the remainder for coal, coke and refined petroleum products [5].

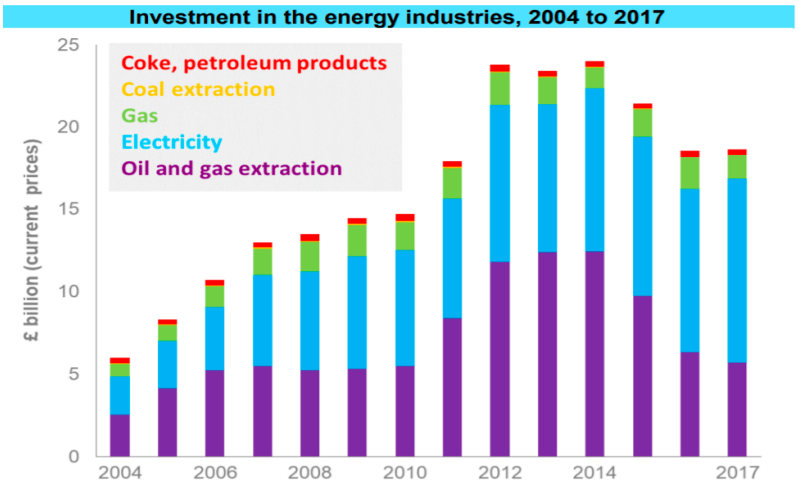

Figure 1. Investments in the UK Energy Industry from 2004 to 2017, showing a declining trend of investments in the last four years.

From the overall investments data recently released by the Office for National Statistics [5], it is apparent that there is a general decline in investments in energy. Hence, whilst Brexit may not be expressly blamed for this trend, it appears that blaming this situation on the recent decline in oil prices of 2014 alone might be a costly simplification of the causal factors and lead to an eluded solution to the problem. For instance, even with oil price recovering from below $30 a barrel a few years ago to over $70 a barrel in 2018, "drilling activity in the North Sea has remained at record low levels, having fallen 50 per cent over the past five years to become "a serious concern" [4].

In 2018, only four exploratory wells were drilled between January and August, the lowest record since 1965. Meanwhile shale gas company Cuadrilla is said to have spent over £100 million on its first fracked well with no revenues yet [22]. At the same time, it is argued that the slow progress of fracking in the UK owing to environmentalist groups' pressure activity, the incidence of lawsuits against fracking companies, and local authorities' reluctance to approve planning requests by fracking companies have cost the industry lots of their risk capital. It is reported that Cuadrilla, the leading giant of the UK's fracking industry, has only just managed to reduce its losses to $11.54m in 2016 from $17.7m in 2015 via a $5.5m reduction in operating and administrative expenses [22].

For shale gas, it would appear that three factors–negative public perception, uncommercial production and Brexit are immediately responsible for the current level of investments. First, the intrinsic uncertainty about recoverable volumes and satisfactory economics of the nascent fracking industry is enough to 'put investors off'. The likely success of fracking in the UK is still unknown and investor fears of losing their investments are apparently starving the fracking industry of investments. We argue that negative investor behaviour and attitude towards UK fracking is further exacerbated by the freely available information about the "collapse of shale gas prospects . . . " in Poland [23] as Poland offers an unfortunate but perfect example of the potential instability of the new fracking industry of the UK. In Poland, wells were drilled and gas flowed, but rock fractures quickly closed, and reduced gas flow to a trickle, and necessitated a halt to operations [23]. The consequence of this geological and fiscal failure for Poland has been witnessed as falling investments since 2015 with US oil and gas giants ExxonMobil, Chevron and Marathon Oil, all walking away from Poland [24–26]. In the UK, some investment analysts believe investing in fracking is far from safe and the investing public has this information freely available [23,27,28]. Indeed, the London Stock Exchange LSE has listed publicly traded shale gas companies, including iGas, at the riskier end of the markets on its Alternative Investments Markets (AIM), making it a less likely investment option for most investors. The fracking industry, in a consultative meeting with the DBEIS Minister has expressed difficulty in obtaining funding from British banks, due to negative public views of fracking [29]. Consequently, in the UK fracking capital comes from foreign investors or from private investors [29], a big contrast to

the situation in the US, China or Canada. The UK lost major oil and gas companies potentially major public company investors BP, Shell, Total, Centrica, among other companies in 2015 as they surrendered a whopping 56% of fracking licences awarded them in the 14th Onshore Licensing Round, some for reasons of unconvincing geological results [30]. Thus, whilst there is geological uncertainty about fracking in the UK, the combined effect of this and unfavourable public perception of the technology, appears to be starving the nascent shale industry of capital required to fund mass development that could revolutionise natural gas production in the UK.

Secondly Brexit, it is believed presents lots of uncertainty about the future of businesses in the UK [31]. The Financial Times estimates, based on the OFNS data, that between 2015 and the first quarter of 2018, the UK recorded £27.8 billion less business investment, noting the general growth of business investments slowed from an average of 5.2% prior to 2015 to only 2.6% per annum after 2015 [3]. The analysis also reveals the UK oil and gas sector grew 5% per annum between 1999 and 2010 and peaked at 9% in 2013. Nonetheless, following the 2014 oil price crash, business investment growth receded to just below 0.9% per annum. Assuming investments in the oil and gas sector continued at the 2013 average, business investments between 2015 and the first quarter of 2018 would have been £25.8 billion more than it currently stands, explaining nearly all the underinvestment, and suggesting Brexit may not be blamed immediately for the underinvestment.

However, as Professor Mizen of Nottingham University puts it " . . . the shadow of Brexit is still hanging over UK businesses" [32,33] and cannot be removed from any analysis of possible factors for the UK's slowed business investments. Whilst there is no direct data that suggests Brexit has negatively affected investments in shale gas, it is apparent that the sheer uncertainty that accompanies Brexit may have induced a significant amount of investor aversion to UK businesses which could have affected shale gas investments too. In fact, some economists argue that had it not been the perceived risks induced by Brexit, general business investments, including in shale gas, would have grown more than it currently stands [3]. This hypothesis is consistent with theories on UK foreign direct investment (FDI) post-Brexit, predicting an apparent loss of FDI ranging 14% to 38%. FDI explains investments from outside a country by mostly multinationals to start new businesses, expand established businesses or acquire domestic companies. It is reported the UK's stock value of FDI is about £1 trillion and about 50% of this comes from EU member states UKTI [34] and Dhingra et al. [35,36] report the UK's EU membership has increased its FDI by 28%. Relatedly Welfens and Baier [37] find empirical evidence to suggest the UK will have reduced FDI post-Brexit.

For oil and gas investments, political factors and an unstable investment climate have been found to increase investor risk premium of doing business [38–42]. Although, the oil and gas business is global in nature and companies do operate in politically unstable regions of the world, these regions have been cited to have prolific reserves potential which supports company business cases, to take on the higher than normal risks of developing hydrocarbons there. Given the shadows of Brexit are over UK businesses, and the grave uncertainty about recoverable reserves of shale gas in particular, it is likely true the UK may be riskier for shale gas investments as suggested by investment analysts. Geological uncertainty may only be reduced with exploratory drilling. However, exploratory drilling requires investment, yet Brexit may have increased investor risk premiums for shale gas and potential fracking investors may have reflected such risks in their economic models, which would most likely render the investments more expensive and less viable. The Financial Times [3] notes that perceptions of a "no deal" Brexit are growing and have been raising the cost of financing for companies, whilst the Governor of the Bank of England, Mark Carney, has argued that business investments would have accelerated significantly, if not for the negative effects of Brexit. We argued on the back of these evidences that the current Brexit climate may have deprived the UK fracking industry of additional investments and that a quick conclusion of Brexit negotiation is as necessary as a favourable Brexit deal to boost shale gas investments, if the UK is to fully commercialise its natural gas from tight shale formations.

2.3. Brexit and Regulation of UK Fracking

Fracking is heavily regulated in the UK. There is a visible presence of government machinery to oversee the permitting for exploration, development and production of oil and gas including the regulation of all aspects of the commercial production of shale gas [43]. The Oil and Gas Authority (OGA) (Department of Enterprise, Trade and Investment—DETI for Northern Ireland) regulates upstream oil and gas activities and grants consents to companies for onshore oil and gas operations, along with a host of other government institutions that oversee health, safety and environmental issues, infrastructural issues, and community matters regarding fracking. Responsibility for licensing onshore oil and gas operations in Scotland passed to the Scottish Minister on 9 February 2018. Fracking is currently most active in England out of all the UK countries and the analyses of this paper majorly relate to England. The Infrastructure Act 2015 simplifies the procedure for obtaining onshore oil and gas exploitation licence [43] and the DECC's [44] report on shale gas exploitation in the UK contains a comprehensive presentation on the regulation of UK shale gas along with best practice. These regulations are nonetheless inspired by the EU legislation that authorise the prospection and development of hydrocarbons in the Member States albeit the competence to find and exploit suitable energy sources rests with the Member States and not the EU [45]. There are varying amounts of potential shale gas reserves in the European Member States and members of the EU do not agree on the benefits and disbenefits and hence the approach to regulating shale gas exploitation in the Union [45]. Some members have thus cancelled and or banned fracking licences and operations, but others are still exploring for shale gas, the latter includes the UK. There is no evidence of a strong regulatory influence of the UK's fracking industry from the EU as much as there is of UK Government institutions including local authorities. The same EU laws that apply to exploration and exploitation of conventional hydrocarbons apply to fracking [45]. Perhaps the most crucial declaration and influence the EU's fracking policy may have on UK fracking is the requirement of fracking companies to declare the composition of fracking fluids to the public, but this is part of non-binding recommendations adopted by the European Commission in January 2014 for the development of shale gas [46]. Whilst, these recommendations mostly relate to environmental aspects of fracking, the UK public and the government are perhaps as vigilant in this area as the EU itself and it is unlikely that any aspect of the existing environmental protocols will change significantly due to Brexit.

3. UK Energy Security Implications

3.1. UK Energy Security Situation

Natural gas is essential in the UK's energy mix as eight out of 10 homes use gas for heating and it is an essential feed stock for manufacturing industries. Three TCF of natural gas is consumed in the UK annually, accounting for a third of the UK's energy supply [47]. UK gas consumption has more than doubled since the 1990s [11]. Currently, at least 40% of electricity generation is from gas (Figure 2). Meanwhile, domestic production of natural gas has declined steadily since the 1990s, exposing the UK to high volumes of natural gas imports annually. In 2017, the overall net energy imports were 36%; with natural gas and crude oil making 90% of total energy imports [5,48,49]. Island Gas [43] notes that the UK currently imports 50% of its gas consumption while the Oil and Gas Authority (OGA) projects that gas imports into the UK could exceed 70% of total gas consumption by 2030 [46]. In 2017, 75% of gas imports came from Norway, 10% from Belgium and Holland and 15% LNG—84% of which came from Qatar [5]. As shown in Figure 2, natural gas is by far the largest source of electricity in the UK.

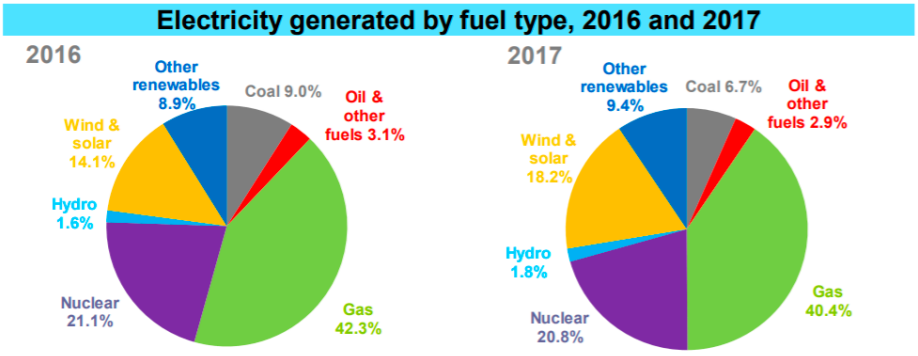

Figure 2. Relative share of natural gas in UK electricity production.

The UK government is thus optimistic that a replication of the US shale gas revolution in the United Kingdom will increase domestic gas supplies, reduce gas imports, reduce domestic gas prices and generally increase energy security [10,50]. Consequently, the UK government has declared Shale gas development a national priority [50]. Figure 2 showing the UK's dependence on natural gas at 40% for its electricity generation and its need for continued supplies [5].

The UK's widening energy import dependency (Figure 3) should be a cause for concern about the security of supplies, and the cost of natural gas and electricity to UK residents and UK businesses. In 2017 alone, prices increased on all fuels for both industrial and domestic users—electricity and gas prices rose 3.5% and 4%, albeit a decrease of 9.9% over the last five years. From 2007 to 2017, real gas and electricity prices increased by 32% and 35% respectively [5]. Fundamentally, the price of most fuels are influenced by crude oil prices [51,52]. Brent crude oil prices have remained relatively low between $44 and $54 in 2016 and 2017 respectively [5]. It is argued that a rise in Brent crude oil prices will sure drag natural gas prices higher, implying an even higher cost of energy for UK businesses and households. Between January and July 2018, Brent crude oil prices averaged over $70 a barrel [53] and it saw natural gas prices increase over the same period (Figure 4).

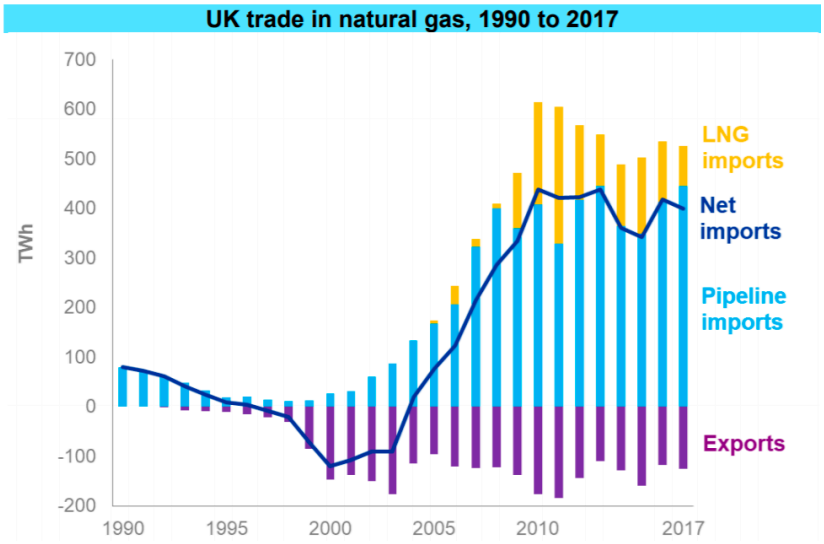

Figure 3. UK Energy Import Dependency from 1970 to 2017 [5].

The reverse is however unlikely as it has been noted that a reduction in crude oil prices since 2012 increased both domestic and industrial energy bills, except for industrial gas bills which fell by 29% [5]. In the UK the Government's public attitude tracker survey 21 (WAVE PAT 21), stated it was reported that 30% of UK households expressed worry about paying for their energy bills which had increased 28% from 2016 to May 2017 [54]. Nonetheless, it appears that declining domestic energy production vis-à-vis attendant increasing imports of energy is the responsible factor and it seems energy bills are

set to continue to increase except with the intervention of significant domestic production of energy in the UK.

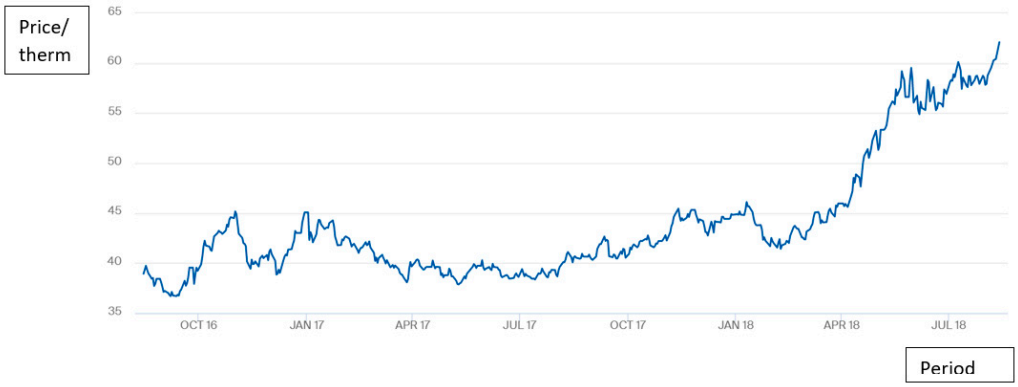

Figure 4. A 2-Year Natural Gas Prices (October 2016–July 2018): September 2018 UK Natural Gas Futures, Showing UK natural gas prices traded less than £0.45 per therm for a large proportion of the last 2 years. Source: [55].

3.2. Brexit and Effects of Trade Protectionism

The UK's cross border trade in energy with the EU Member States is easier and cheaper due to its membership of the Union and the Internal Energy Market. Thus, there are no tariff or non-tariff trade barriers between the UK and EU but Brexit could change this as well as the UK's trade relationship with non-EU countries. Should the UK opt to trade energy with the EU following a hard Brexit, protection barriers may apply to a host of trade transactions, including energy and this may render energy and energy related imports from the EU more expensive [56].

The European Commission (EC) under its Market Access Strategy (MAS) along with the Market Access Partnership (MAP), identifies trade barriers, negotiates and seeks to induce policy change by its trade partners so as to ease access by its member states into third countries for the purposes of doing business. In 2017, the EC reports that it partly or fully removed 45 trade obstacles through its enhanced MAS. This was more than twice the number removed in 2016. Additionally, in 2016 36 new trade restrictions that could have cost the Union some Euro 27.17 billion in exports were removed. These savings were estimated at Euros 8.2 billion in 2017 [57,58]. Trade barriers in 2017 spanned 13 EU trade and investment sectors and covered aircraft, automotive, ceramics, ICT and electronics, machinery, pharma, medical devices, textiles, leather, agri-food, steel, paper, and services sectors. As a result of the removal of barriers between 2014 and 2016, the EU was able to earn additional Euros 4.8 billion in from exports in 2017 but at the same time, in 2017, 67 new trade obstacles were recorded, raising the total number of protectionist trade barriers to a whopping 396 across 57 EU trade partners. Russia and China are recorded to have the highest number of trade protectionist instruments at 36 and 25 respectively as in Table 1.

China does not appear to be a great threat to a potential UK bilateral relation, but Russia does. Russia currently has a strained relationship with the UK, EU, US and other coordinated Western allies, for its "destabilisation of Ukraine and annexation of Crimea" [59] and more recently its alleged connection with the Salisbury attack of March 8th, 2018 in the UK. Table 1 shows Russia has consistently held the most trade barrier instruments against EU trade partners and that it could raise new trade barriers against the UK post-Brexit, due to the latter's lost privileges from the EU MAS.

UK does import LNG from Russia and due to stressed relations and tensions, fresh trade restrictions could be introduced between the UK and Russia post-Brexit, especially if the MAS no longer shields the UK. Such could increase the import cost of Russian natural gas. Nonetheless, UK imports less than 1.5% of her natural gas from Russia in 2018 compared with Europe's imports of 37% in 2016 from Russia [60,61], and that could prove to be a great relief the UK. On the other hand, the UK could cease to provide a market for Russian LNG and replace this proportion of LNG imports

with imports from trade partners such as Qatar, Malaysia or even Australia. Together, the coordinated move by the EU, US and other Western allies have many trade barriers and sanctions against Russian individuals and corporations, including three oil and gas companies until 31st July 2018. In reaction to the Salisbury attack, 25 countries expelled 130 Russian diplomats and the EU Ambassador to Russia was withdrawn [59].

Table 1. Top Ten Trade Barriers Against EU Countries in 2016 and 2017 by Country [57,58].

No.	2016		2017	
	Country	No. of Barrier Measures	Country	No. of Barrier Measures
1	Russia	33	Russia	36
2	Brazil	23	China	25
3	China	23	Indonesia	23
4	India	23	India	21
5	Indonesia	17	Brazil	21
6	South Korea	17	South Korea	20
7	Argentina	16	Turkey	20
8	USA	16	USA	20
9	Turkey	15	Australia	14
10	Australia	13	Thailand	12

The UK has been a beneficiary of such privileges as a member of the EU. Post Brexit, such benefits could be removed. On the other hand, this would accord the UK the opportunity to craft her own energy policy with domestic priorities, including protectionist strategy/ policy both for its trade relationship with the EU and other trade partners it may identify, without the burden of current EU restrictions. For example, the UK may lose the Inter State Aid but this grants her the opportunity to "target her energy policy support at energy generation technologies without the State aid restrictions" [56]. The House of Lords' ESC report on Brexit and Energy Security presents detailed evidences on tariff and non-tariff tools that could apply post-Brexit but which fall outside of the scope of this research. For UK fracking, it does not appear that protectionism by the EU or other countries will pose a great threat to the industry. For example, the EU's average tariff on industrial goods is only about 2.3% [62]. Such, is not expected to cause significant changes to current investments in fracking.

4. The Moderating Effects of Shale Gas on UK Energy Price

4.1. The Potential of Shale Gas for the UK and Gov't Expectation

Recoverable volumes of shale gas in the UK are uncertain and depend on the results of exploratory well drilling. The British Geological Survey's (BGS) current estimates of the geological potential of shale oil and shale gas within the UK stand at 1,419.6 Tcf and 11.5 billion bbl respectively and cover parts of England, Scotland and a small area of Wales in the Upper Bowland Hodder. Table 2 presents the BGS's estimates of in-place shale gas and oil in the UK.

Table 2. P50 Estimates of Shale Gas and Oil Resources in the UK [63].

Basin	Shale Gas (Tcf)			Shale Oil, (Billion bbl)			Date Announced
	P10	P50	P90	P10	P50	P90	
Bowland Shale	2281	1329	822		-		27-Jul-13
Midland Valley of Scotland Shale	134.6	80.3	49.4	11.2	6.0	3.2	30-Jun-14
Jurassic Shale of the Weald Basin		-			4.4		23-May-14
Jurassic Shale of the Wessex Area		-			1.1		-
Wales		10.3					26-Jun-14
Total		1419.6			11.5		

The former Conservative Prime Minister, David Cameron in underscoring the Government's expectations from shale gas is reported to have indicated that recovering just 10% of the Bowland Shale alone, could supply about 51 years of the UK's natural gas demand [5]. Meanwhile Cuadrilla Resources Ltd., the operator of the Bowland shale estimates a central annual production rate from the Bowland shale alone to be 3.5 billion cubic metres (Bcm) [64]. If these estimates are anything good to go by, it would be a significant facelift to UK energy supply and security. The US EIA [65] believes that 26 Tcf of the UK's shale gas is technically recoverable. The IoD shares the optimism for shale gas extraction and projects that producing the UK's shale gas could result in as much as 39 per cent reduction (from 76% to 37%) in natural gas import by 2030, and reduce the Government's natural gas imports bill from £15.6 billion to £7.5 billion, saving some £7.5 billion, in 2012 prices [66]. The economic savings by households and industrial electricity and gas users from such a significant shale gas production would be enormous. As an example, between 1980 and 2000, a rapid increase in domestic natural gas and crude oil production kept domestic and industrial electricity and gas bills at record low levels [5]. The DBEIS again reports that gas and electricity prices more than doubled over the period from 2002 to 2016, except for 2016 when prices decreased due to increased domestic gas production [5,67–69]. The period 2002 to 2016, coincides with the peaking and subsequent falling of North Sea production and consequently increased imports from -11 % in the year 2000 to an average to 47% gas imports in 2016 (see Table 3). Both domestic and industrial gas and electric bills have been on an upward trajectory since 2004 [70] .In 2016 however, industrial gas and electricity prices decreased 17% and 4% respectively whilst domestic prices fell 7.5% for gas and 1.9% for electricity over 2015 (Tables 4 and 5). These price reductions were linked to the start-up of the Laggan and Cygnus gas fields in mid-2016 and December 2016 respectively to contribute 6.5% to domestic gas production [67]). The Laggan gas field is projected to contribute between 5% and 10% to "all UK production in the next few years" [67]). By extension, significant domestic production, whether from conventional or unconventional sources, will have varying degrees of moderating effects on both domestic and industrial energy prices, and thus contradict hypotheses that shale gas will not lead to reduced UK gas price [71] (Roger 2013). It would therefore be safe to indicate that a significant shale gas production should reduce domestic gas and electricity prices. Such reasoning is consistent with predictions of reduced UK gas prices upon commercial production of shale gas [8,66]).

Table 3. Average (percentage) Net imports of Natural Gas at c.35% from 2000 to 2016 (Percent) [a].

Fuel	2000	2010	2013	2014	2015	2016	6-Year Average
Coal	39	52	84	87	60	46	61
Gas	−11	40	52	47	43	47	36
Oil	55	14	40	43	37	34	37
Total	−17	29	48	47	38	36	30

[a] Table 3 shows the average natural gas imports for six years, showing the UK imported on average, 36% of her natural gas over the period indicated. With IoD estimates and Government expectations of shale gas production, the UK's natural gas import dependency could be resolved to reduce domestic and industrial gas and electricity prices considerably [67].

Table 4. Real Industrial UK Energy Prices (Including VAT) from 1996 to 2016, with 2010 = 100. Source: [67]).

Fuel	1990	2000	2010	2015	2016
Coal	99.1	62.7	100.0	93.4	86.1
Electricity	84.1	60.0	100.0	112.3	107.9
Gas	72.4	45.4	100.0	110.4	91.7
Heavy Fuel Oil	25.9	33.3	100.0	70.7	69.5
Industrial Prices	74.4	51.9	100.0	105.2	98.7

Table 5. Real Domestic UK Energy Prices (Including VAT) from 1996 to 2016, with 2010 = 100. Source: [67].

Fuel	1996	2000	2005	2010	2015	2016
Solid Fuels	62.4	61.0	70.8	100.0	105.2	103.2
Electricity	86.4	70.3	73.9	100.0	118.7	116.4
Gas	59.9	52.0	63.3	100.0	122.3	113.1
Liquid Fuels	48.4	55.1	74.0	100.0	75.8	66.5
Domestic Fuels	71.5	61.6	69.4	100.0	119.0	113.5

The UK Onshore Operators' Group, UKOOG, notes that shale gas will help reduce the UK's carbon footprint as it will displace coal production in the energy mix [8]

4.2. Brexit, Energy Price and the Role of Shale Gas

In the US, the share of shale gas in the energy mix, rose from 1% to 20% in 10 years, from 2000 to 2010 according to Stevens [12]. In 2016, the EIA believes that 15.8 Tcf of dry natural gas was produced from shale and tight oil resources, accounting for about 60% of US dry natural gas production; 81.1 Bcfd in 2018 [72,73]. The benefits from shale gas in the US have been reaped in the form of reduced electricity and gas prices, even in the face of increasing gas consumption, job creation, etc. [74]. For example, the average Henry Hub gas price from 2015 to Nov 2017 was less than $3 per million Btu [75]. Consequently, the US government anticipates supporting the unconventional gas industry in order to sustain lower gas prices from the impact of shale and tight gas production.

Uncertainty surrounds the UK's shale gas estimates at this early stage, and this has resulted in mixed anticipation of its potential contribution to the UK economy, businesses and households. Nonetheless, from a purely economic standpoint, it is possible to characterise the conditions under which the potential benefits of shale gas production may or may not be derived. Following basic laws of demand and supply, a hard Brexit is expected to lock in outflows of UK produced shale gas into the EU's Internal Energy Market (IEM), where it could otherwise sell at a higher price and ultimately remove the benefits of cheaper gas prices from UK residents. In essence, similar to the implications of US shale gas, of excess natural gas supply, LNG capacity utilisation growth and lower gas prices; UK shale gas could cause an additional supply of natural gas at least within the UK, and force gas prices downwards and consequently reduce energy prices. It is to be noted however, that Stevens [11] warns such theory only holds true under a UK-only gas market; and by implication under a Hard Brexit only that presents a closed energy market, one similar to the US's energy market structure which essentially locks immediate additional gas supply to a UK–only market. Stevens [12] explains that as the UK gas price falls, the country's physical connection to the European Gas Market via the Batcon interconnector could encourage arbitrage as market participants look to trade cheaper UK gas in the higher- price European gas markets, which eventually would push UK gas prices up. This is why the author believes that the theory that shale gas would decrease UK gas prices is a myth. Thus, a soft Brexit would render the benefits of reduced gas and electricity prices an illusion. Nonetheless, the analytical review in the section on IEM and Energy prices extends this discussion and characterises the conditions under which shale gas may or may not reduce energy prices.

4.3. The IEM, Natural Gas Trade and UK Energy Supply and Prices Post Brexit

The EU's Internal Energy Market (IEM), introduced in 1988, aimed at facilitating free trade, particularly the energy trade within the EU [76]. Currently, the IEM rules permit the use of cross-border infrastructure to facilitate the import and export of energy produced in member states without the burden of transport tariffs being applied [77]. Thus, consumers of energy in EU member states may pay lower, all things equal, for energy under IEM arrangements. The UK imports about 60% of its energy. Except for gas, imports of all energy types declined in 2016. In 2016, 65% of the UK gas import was from Norway's Continental Shelf [67,78]. Of the UK's gas import of 532 TWh in 2016,

an insignificant amount was imported from the interconnector via Belgium in the last ten years to 2017 and the combined UK import of natural gas from interconnectors, including the Netherlands were found to be much lower than the total exports of natural gas from the UK into Europe as seen in Figure 5. The evidence suggests that the UK exported on average 5,191 GWh of natural gas to Europe via interconnectors. This significant net export to the EU as in Figure 5, would stay within the local UK gas market to boost domestic supply and fill local demand gaps should the UK opt out of the IEM post-Brexit. As seen in Figure 5, there has been an upward trajectory of net natural gas exports from the UK into Europe since 2012—an important revelation of the relative positions of the EU and UK on energy trade. We argue on the back of this evidence that an increase in domestic gas supply from shale gas production, which would result in additional supply will put downward pressure on natural gas prices, a major source of electricity production in the UK and thereby reduce industrial and household energy prices/bills.

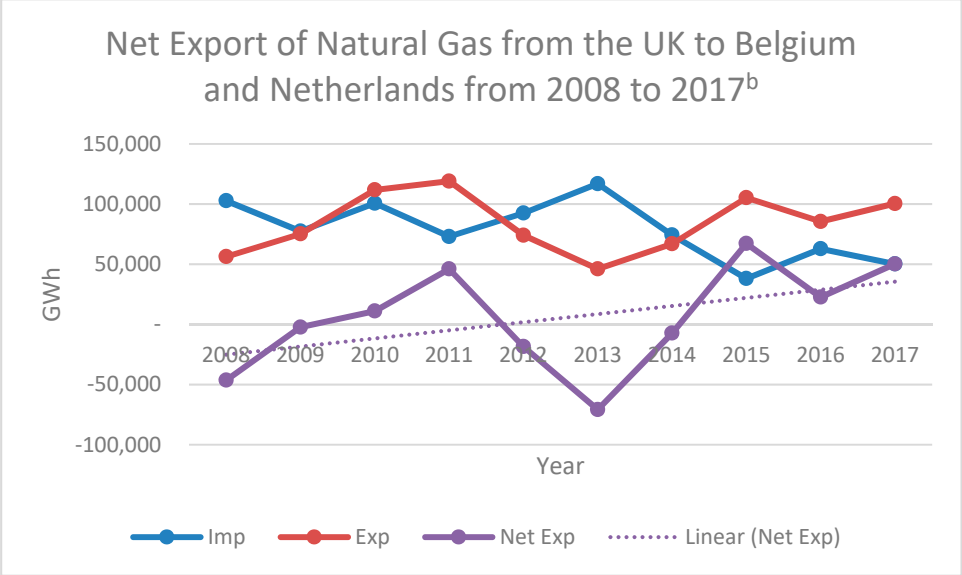

Figure 5. The UK's Import and Export of Natural Gas via the Belgium and Netherlands from 2008 to 2017. ([b] Net Pipeline trade of natural gas via interconnectors showing that the UK in the last 10 years has exported more natural gas to Europe (an average of 5191 GWh per year) than it has imported. This evidence supports the argument that post-Brexit, the UK will benefit from any additional domestic natural gas production from shale through reduced energy prices. Source: [79])

It is believed that shale gas will lead to reduced energy prices for the UK [80] but there are others who suggest this is not the case [11,12,71]). Commercial extraction of shale gas in the UK has not started yet, but it is possible to characterise the conditions under which shale gas production could influence energy prices. Also, although it has not left the IEM yet, it is possible to draw lessons from the US experience and also characterise what is likely obtainable in the UK based on the evidence available on UK natural gas. Indeed, the UK shale gas industry and government institutions have relied on such analysis to construct an envelope of likely obtainable benefits from shale gas in the UK [63,81]. For, example IoD 66], suggests among other advantages and benefits, that shale gas has the potential to reduce the UK's import dependency to just 36%, a drastic reduction from 76% without shale gas production. This conclusion again contradicts popular studies such as Stevens [11,12] and Rogers [71] who believe import levels and prices are unlikely to change due to shale gas production.

US shale gas revolution has changed world energy flows. As reported by the US EIA [73] the US is a net exporter of natural gas. Consequently, there is now more liquified natural gas LNG available for European and Asian markets. This surplus is in addition to US net exports of NG which averaged 0.3 Bcfd in 2017 and is forecast to increase to 2 Bcfd in 2018 and 5.4 Bcfd in 2019 [73]. In addition, the US

now exports more coal to Europe and Asia because this portion has been replaced by natural gas from shale, for electricity generation [82]. The increased availability of LNG in Asian and European markets without a doubt does have an effect on prices in those markets.

The UK imports gas via four main subsea pipelines as in Table 6. The IUK is the only bidirectional pipeline with the capability to flow gas from Belgium to the UK and vice versa, depending on the demand-supply and price dynamics between the two countries [83]. Although, with nearly as much capacity as the Norwegian Langeled Pipeline, the IUK is less utilised for imports into the UK compared to the combined imports from Norway. In 2017, the UK imported 75% of its natural gas from Norway and this has been the trend for many years [5,11]. Nonetheless, the crucial role played by the interconnector in providing 'balancing gas' to augment the UK's more reliable supplies from Norway, as well as offering UK gas companies arbitrage opportunities, may be lost should the UK opt out of the IEM. Yet, the UK still has the choice to negotiate bilateral trade with the EU under one of three options suggested by Ifelebuegu et al. [18]—the European Economic Area trade rules, Comprehensive Economic and Trade Agreement (CETA) or the EU-Swiss Model. Furthermore, the UK has the infrastructural readiness to increase LNG imports as a short-term energy source to replace most of the gas from EU interconnectors. That said, immediate benefits that derive from the IEM may be lost to the UK but there may well be imminent opportunities too, especially with the potential commercialisation of shale gas in the UK. Stevens [11] believes reduced UK energy prices due to shale gas is a myth. The author argues that as UK gas prices fall, the country's physical connection to the European Gas Market via the Batcon interconnector could encourage arbitrage as market participants look to trade cheaper UK gas in the higher- price European gas markets, which eventually would push UK gas prices up.

Table 6. Major UK Natural Gas import pipelines and Origin. Source: [83].

No.	Name	Capacity per Year	Percent
1	The UK-Belgium Interconnector (IUK)—a bi-directional pipeline	25.5 BCM	31.8
2	The UK-Netherlands pipeline	14.2 BCM	17.7
4	The Vesterled Pipeline Link—Connects Scotland to Norwegian Gasfileds	14.2BCM	17.7
4	The Langeled Pipeline—connects England to Norway	26.3 BCM	32.8
	Total	80.2 BCM	100

Following basic laws of demand and supply, the rationalisation may hold true that a Hard Brexit is expected to lock in outflows of UK produced shale gas to the EU's Internal Energy Market (IEM), where it could receive a higher price and ultimately remove the benefits of cheaper gas prices from UK residents, whereas a Soft Brexit may erode any benefits of lower UK gas prices from shale gas production due to arbitrage activity as suggested by [11]. It is to be noted however, that available evidence from 2016 fails to support such theory. In addition, it appears that a very large scale of shale gas investment that results in significant recovery of shale gas may weaken this idea.

In this research, it is argued against popular theories of no reduction in energy prices from shale gas [11,12,76], that whether the UK remains within the IEM or not, significant shale gas production could reduce gas price and the scale of reduction will be positively correlated to the scale of shale gas recovery from tight rock formations. As an example, in 2016, a 6.5% domestic increase in UK gas production over 2015 resulted to 17% and 4% reduction in industrial and domestic gas price respectively, whilst electricity prices reduced 7.5% and 1.9% respectively. It is important to note that, during this period the UK remained a member of the IEM and companies engaged in arbitrage trading. In fact, the UK exported 116.9 TWh (25%) of its natural gas production in 2016 compared to 159.5 TWh (35%) in 2015 [67]) and yet had reduced gas prices. Overall, the UK natural gas production edged up by 2.3% in 2016 than 2015, but that was all it required to trigger the significant energy price savings above. Although overall imports were higher by 6.6% in 2016 than 2015, a whopping 20% less LNG import was required in 2016 compared to 2015. The UK uses LNG imports to balance its gas supply

deficits from pipelines and this has been the case since 2005. Post-Brexit and given a 'No-Deal' or 'Hard Brexit' with no membership of the IEM, the UK may suffer a combined impact of its lost natural gas and electricity importation via the EU interconnectors. Currently, the UK imports the larger share of electricity via the interconnector from France. In 2016, although electricity import fell 13%, it was 11 TWh. A likely result of a Hard Brexit would include higher energy prices, albeit only in the short to medium term. Indeed Pollitt [84] decries arguments that Brexit will result in increased energy bills. He notes that (1) measured benefits to the UK on its membership of the single energy markets has been small and difficult to quantify, and (2) the gains from market integration have remained under 5% of costs due to limited interconnection capacity. He also observes there were stable and sometimes decreasing energy demand for most EU countries since early 2000, and that appear to have limited trade gains by large economics, including the UK's for the IEM. Pollitt however argues that a hard Brexit may rather benefit the UK by reducing energy prices. He notes that a hard Brexit may lead to a small limitation on net imports of electricity from France and Netherlands, but adds that this is about 6% only, and argues that gains will be made towards reducing UK energy prices from a more significant limitation on substantial export of energy from the UK into the EU. Shale gas production which will increase the domestic supply of natural gas will thus reduce energy prices even further.

The UK could still remain in the single energy market. Post-Brexit, the EU electricity market provides two models of trade that the UK could exploit. The UK could join the European Free Trade Area (EFTA) and through its membership access the single energy markets should it wish to, in the way Norway has stayed a member of the single market, but not the EU. Norway, through its membership of the NordPool and EFTA has full access to the EU electricity markets with all associated benefits [18,84].

Alternatively, Switzerland is fully integrated into the single electricity market but with limited participation in the market owing to the former's rejection of the EU's freedom of movement in 2014 [74], similar to a hard Brexit scenario. Nonetheless, it is acknowledged that the Swiss Model accrues mutual benefits to Switzerland and the EU and the UK could exploit such a relationship with the EU should it opt for a hard Brexit).

Without the EU, the UK has the choice to increase its natural gas imports from Norway through bilateral arrangements via pipeline or import more LNG from elsewhere. Currently, Qatar supplies about 80-90% of the UK's LNG requirements, (this was 15% of the total UK gas demand in 2017) [5,12] and the UK has three LNG receiving facilities with a combined capacity to meet 50% of the UK's annual demand [83]. It has the option to increase imports from Qatar, Nigeria, Algeria, Trinidad and Tobago or from North America. The US exported its first shale gas in LNG to the UK in July 2018 and the editor of Global LNG Markets at ICIS, Ed Cox believes the US is another potential supplier of UK LNG besides Nigeria, Algeria and Qatar [85]. Indeed, the FT reports that US LNG could serve as an alternative for European countries that seek to reduce reliance on Russian pipeline gas [75]. With its shorter distance to the US, Europe is argued by LNG market analysts to favourably compete against Asian LNG importers for US LNG [86].

Fundamentally, the benefits of a closed energy market—one similar to the US's will cause domestic energy prices to reduce significantly due to the replacement of the share of imported gas which was used to generate electricity or consumed by industry, households, services, etc. in the UK by shale gas upon start-up, should the UK exit the IEM. Similarly, if the UK were to remain in the IEM post-Brexit, benefits from shale gas would still lead to a reduction in domestic energy price as witnessed in 2016 with the start-up of the Laggan and Cygnus gas fields. Furthermore, increased energy prices have been linked to periods of lower domestic production and higher imports and exports of gas, whilst lower energy prices have been linked to periods of higher domestic production as seen in 2016, and the period before 2000 until 2004 as in Figure 6. These factors do suggest UK energy prices could significantly reduce with strong recovery rates of shale gas, and such an impact stands to be felt by UK households and businesses whether the UK remains or not within the IEM. This analysis is consistent with the analysis contained in the European Parliamentary Research Service's research on the potential impact of shale gas on EU energy security. The research document offers evidence on and argues

that shale gas may not lead to energy self-sufficiency within the EU but could lead to reduced energy prices [46].

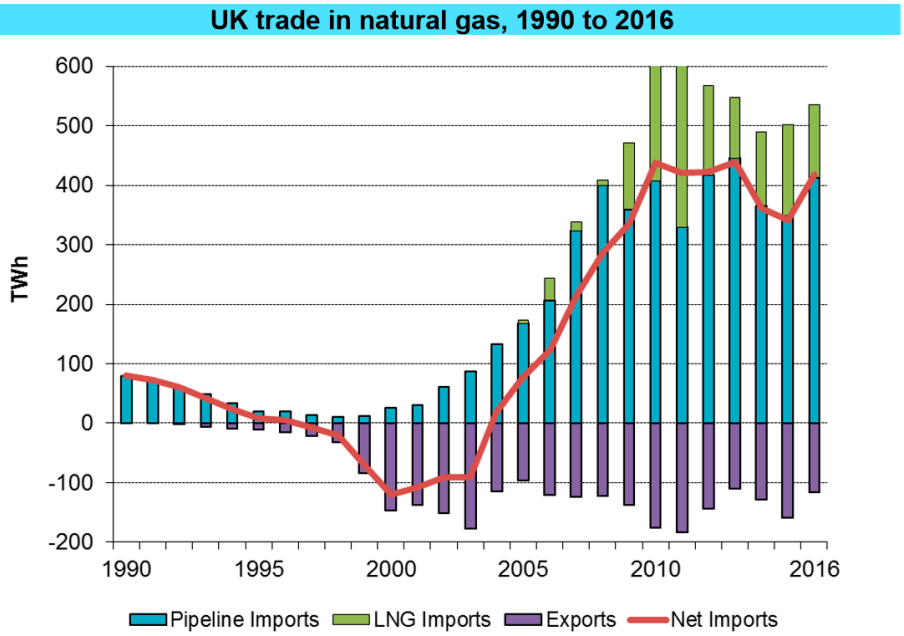

Figure 6. UK Trade in Natural Gas from 1990 to 2016. Showing the UK's growing net imports of natural gas in recent years. Source: [67].

Figure 6 suggests the UK imported relatively less volumes of natural gas between 1990 and 2004 compared with her current levels of natural gas imports in excess of 500 TWh in 2016. The period of lower imports coincides with lower energy prices and higher domestic production of fuels until peaking in 2000 and 2004 for oil and gas production respectively, and thus offer support to the notion that increased domestic shale gas would likely lead to a reduction in energy prices.

4.4. Brexit, Exchange Rates and Energy Prices

It has been recorded that Brexit is to blame for the falling value of the Sterling to the Euro and Dollar since the Brexit referendum. The UK imports a significant portion of its gas as shown in this research, and thus pays more to import gas if the Sterling weakens in value. In a report commissioned by Ofgem, Gissey et.al [87] record that the falling value of the Sterling increased wholesale energy generation costs. The authors provide an intriguing insight that retail energy prices after the Brexit vote were increased just about the same degree to which wholesale energy generation input costs had increased due to the weakening effect that Brexit had caused the Pound Sterling. The authors note that a year following the referendum, wholesale natural gas prices which represent 39% of final consumer gas price increased 16% due to a weaker pound sterling. This phenomenon added £2 billion to UK energy bills; £75 rise in an average energy bill; £39.4 and £35.3 for gas and electricity bills respectively, with similar projections for 2019 to 2020. Meanwhile wholesale costs represent over a third of electricity price paid by consumers [88]. Gissey et al. [87] therefore conclude that the effects of Brexit on energy prices manifest mainly through the impact on exchange rates. They find that the 2016/2017 consumer price increase in electricity prices of 6% corresponds to the increase in wholesale energy costs. We argue on the back of this evidence that a sustained decline in the value of the pound will lead to higher wholesale gas prices and lead to higher retail energy price. Thus, households will pay more. In addition, leaving the internal energy market implies the UK may trade energy less efficiently and this could lead to higher prices. As an example, it is reported by [56] market coupling (an algorithm used to trade electricity on the IEM), worth £100M/year to the UK enables UK companies to automatically match demand and supply efficiently via interconnection and reduce

operating costs. This benefit could be lost post-Brexit as there are no provisions in the IEM for "third countries" [56]. The UK could thus lose this privilege in the same way Switzerland lost it too. This could mean more transaction and intermarket cost per unit of energy production, which may be passed onto final consumers as increased energy prices.

As indicated in the foregoing analysis in Sections 4.1 and 4.3, however, commercial exploitation of shale gas which also constrains the additional production of gas to the UK could reverse this situation, but production of additional gas from shale would need to be expedited to realise and maximise such benefits.

5. Conclusions and Recommendations

Contrary to popular theories on shale gas and UK energy price, the evidence presented in this paper suggests a reduction in household energy bills is possible under soft or hard Brexit scenarios. For a significant domestic shale gas production, the UK stands to benefit from the impact of additional gas injected into its local gas market. Such excess gas, similar to the one seen in 2016 with the start-up of the Laggan field, could reduce energy prices despite arbitrage activities within Europe via interconnectors. Similarly, a hard Brexit which locks domestic UK shale gas production to UK gas markets could have even more benefits and reduce gas and energy prices for UK households and businesses. Nevertheless, Brexit appears to threaten higher energy prices for the UK. It added about £2bn in 2016/17 to energy bills and energy prices are projected to rise due to spillover effects from Brexit. It is evident from the research that a weak Pound Sterling corresponds to higher wholesale energy input costs and thus increased retail energy price. Brexit has been found to weaken the value of the Sterling and a further weakening could lead to increased wholesale gas and electricity costs which in turn represent at least a third of the energy prices paid by UK consumers. In addition, withdrawal from the IEM could lead to inefficient trading of energy by the UK and push energy prices up.

Meanwhile evidence suggests that the UK has the potential to extract significant volumes of natural gas from tight shale formations. It is found that commercialisation of shale gas at current production estimates could potentially replace the proportion of gas imported from Europe via interconnectors and thus remove the impact of exchange rate on the cost of energy generation and wholesale price of energy, leading to reduced consumer price. Importantly, a market arrangement where the domestic natural gas market in the UK shrinks from the open EU IEM to a closed UK-only gas market will manifest benefits similar to that of the US's shale gas for US households and businesses due to additional supply at equilibrium demand levels. Sadly, however, it appears that the uncertainty that accompanies Brexit, has starved the UK energy industries including the nascent fracking industry of critical investment capital required to develop shale gas and the fact that the resource is being developed first time may have even worsened this situation. The current research argues that, such negative consequences could be curtailed by expediting natural gas development projects that bring new supplies onstream as they have proved to moderate price as seen in 2016 with the start-up of the Laggan and Cygnus gas fields. Shale gas development and exploitation offer huge potential and some hope for UK energy consumers, but its development must be expedited in order be able to cash in on, and maximise any benefits from it.

The results of the current research are based on conjectured shale gas recovery factors. Whilst such analysis is acceptable, it would have been more valuable to be able to empirically test the extent of the impact of shale gas production on wholesale gas price and the eventual implication for final consumers, especially the extent to which shale gas reduces retail gas price. Quantitative simulation of such relationship based on shale gas production data would enable improved quantification of the benefits of shale gas to the UK energy consumer. Such research should be conducted as soon as the requisite data becomes available from shale gas operating companies. It is also recommended that further studies be conducted on the options the UK Government has for expediting shale gas exploitation, especially focusing on the changing landscape of energy resource development and fiscal policy.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, E.A.-A.; Methodology, E.A.-A.; Software, E.A.-A. and A.O.I.; Validation, E.A.-A. and S.C.T.; Formal Analysis, E.A.-A. and A.O.I.; Investigation, E.A.-A.; Resources, E.A.-A.; Data Curation, E.A.-A., A.O.I. and S.C.T.

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