Economics and Politics of Shale Gas in Europe

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Executive Summary

As in many other regions, the success of unconventional gas in the United States, has generated interest in many European capitals in replicating that experience. The appeal of shale gas exploitation is driven by a combination of concerns over the impact of rising energy costs on industrial competitiveness and the perceived risks of disruptions to European gas supplies from increasingly more serious political crises along its eastern border in Ukraine.

Analysis of a possible shale gas revolution in Europe have largely drawn from the US shale gas experience to understand the economic, political and environmental impacts. Most economic analyses assume averages for such important parameters as well productivity and drilling performance. The conclusion they make based on these analyses is that the economics of shale gas in Europe is marginal, and that environmental and other constraints (e.g., upstream service sector) could undermine the economics and hence if shale gas in Europe is to be developed at all, it would occur at a much more modest scale than in the U.S..

However, applying average well productivity and/or costs ignores a crucial fact that only a small fraction of wells drilled are critical to the overall economic success of any shale gas lease. The developer's objective is therefore to understand why certain wells succeed and how to replicate the success for subsequent wells. In other words, economic analyses that rely on average numbers do not reflect the reality of shale gas production economics. A more robust way to treat uncertainties surrounding shale gas economics is to conduct a stochastic analysis of its main components (well productivity, cost along the value chain, drilling productivity etc.).

The risks and uncertainties associated with conventional gas production are minimal compared to shale gas production. By contrast, exploration for shale gas is not a risky business since shale gas is a source rock and is abundant; rather, the risks of shale gas development are shifted from the exploration phase to the production phase because shale gas extraction is much more complex and well productivity varies greatly even within the same shale formation.

The highly stochastic nature of shale gas production favors small exploration and production companies with greater flexibility and higher risk appetites. In other words, traditional oil and gas integrated majors, being more risk averse than smaller independents, operating in the same (risky) environment would take a more cautious investment strategy. Risk-taking is essential for successful shale gas production due to the need for improved geological knowledge and operational efficiency, which ultimately lie at the heard of cost reduction.

The very steep decline in the production rate of shale wells means that shale producers would require access to local markets to monetize their reserves. In particular, access to the pipeline network and cost of access is an important factor. Thus, liquid, transparent and competitive wholesale gas commodity and transportation markets are essential to the success of shale gas in Europe. Further, the risk profile of independent shale producers is concentrated on production and traditional hedging such as moving along the gas value chain (e.g., by moving downstream) is not effective, they would require financial risk hedging tools to shield their production positions.

In spite of moderately sized reserves and growing energy security concerns, a number of EU member states have chosen to effectively shut down exploration in the face of widespread public and NGO opposition. Several of Europe's largest gas markets including France, the Netherlands and Germany, which together constitute over a third of the EU's gas market, have various forms of moratoria on shale gas exploration. On the other hand, energy security is a major driver of shale gas development in Poland and a number of other central and eastern European countries. However, these markets are generally small compared to northwestern European markets, are the least liberalised in the EU, and gas pricing remains regulated or dominated by oil indexation mechanisms. The economic fundamentals for developing shale gas are most attractive in the UK since it has the largest and most liquid market in Europe with rising energy security concerns and a strong government commitment to supporting shale gas activities. The major obstacle is likely fending off public, particularly local, opposition to exploration.

Given the recent developments in Ukraine, European policy makers seem to favor developing shale gas as an option for Europe to diversify its gas imports away from Russia since other suppliers (overseas LNG, Middle East and North Africa etc.) are not very promising in the short to medium term. A more problematic question, which affects both the economics of conventional gas supply options to Europe as well as European shale gas is the future of gas in Europe over the medium term (2025-2030). Diversification away from Russia requires large investment in economic and political capital to develop shale gas and promote investment to develop infrastructure outside Europe. Investors who would undertake those investments will require greater clarity as to the future of the gas markets in Europe that extends beyond shale gas in particular. Given recent developments in European energy policy, particularly the renewables directive, natural gas has been priced out of energy markets in Europe.

Economics and Politics of Shale Gas in Europe

Abstract

In the wake of the dramatic growth in shale gas production in the United States, interest in shale gas exploration in Europe has been driven primarily by concerns over industrial competitiveness and energy security. A number of studies have been carried out to understand the success factors underpinning the US shale gas revolution and how this success could be replicated in Europe. Most of these studies focus on the macroeconomic and energy market impact of a possible shale gas production in Europe. These studies are in general sceptical about the prospects of shale gas development relative to other gas supply options to Europe. By considering the other options available in greater detail and exploring the stochastic nature of shale gas exploration and production as they apply to production economics, we conclude that this scepticism may be overstated. Apart from political opposition that has shut down shale gas exploration in a number of European member states because of concerns over environmental risks, in some countries notably the UK, the combination of political support and a large, liberalised gas market may offer at least a plausible case for shale gas production. To properly assess the potential for shale gas though, a more rigorous, probabilistic analysis of the associated production economics will need to be carried out.

Keywords: Shale gas, Europe, production costs, gas supply options

1. Introduction

Advances in oil and gas drilling, which has facilitated access to unconventional gas and oil, has transformed U.S. energy markets. Through most of the 2000s, the US was expected to be an ever-larger net importer of gas and correspondingly many contracts were signed to build out LNG import infrastructure. As late as 2008, the U.S. Energy Information Administration was predicting continued growth in net imports, and natural gas prices more than double what they were in 2012 (Table 7a and Table 10, EIA, 2014a)

However, due to the rapid development of shale gas, the LNG import capacity and import contracts that were thought necessary to feed the American economy are no longer needed. The shale gas revolution took the U.S. (and global) energy industry by surprise – although there are no major gas export facilities in the U.S. yet, international gas markets have already been influenced by unconventional gas production in the US. Since around 2005, contracted LNG shipments have exceeded actual imports by over 250 mmt[1].

LNG supplies from third countries were therefore able to satisfy increasing global (in particular Asian) gas demand following the Fukushima disaster in 2011, without which import prices would have been higher. The abundance of shale gas depressed U.S. gas price and has created large price differentials relative to other

[1] Authors' calculations based on Bloomberg data

regional markets (Europe and Asia) (Figure 1), creating a pipeline of LNG export project proposals to arbitrage away those differences.

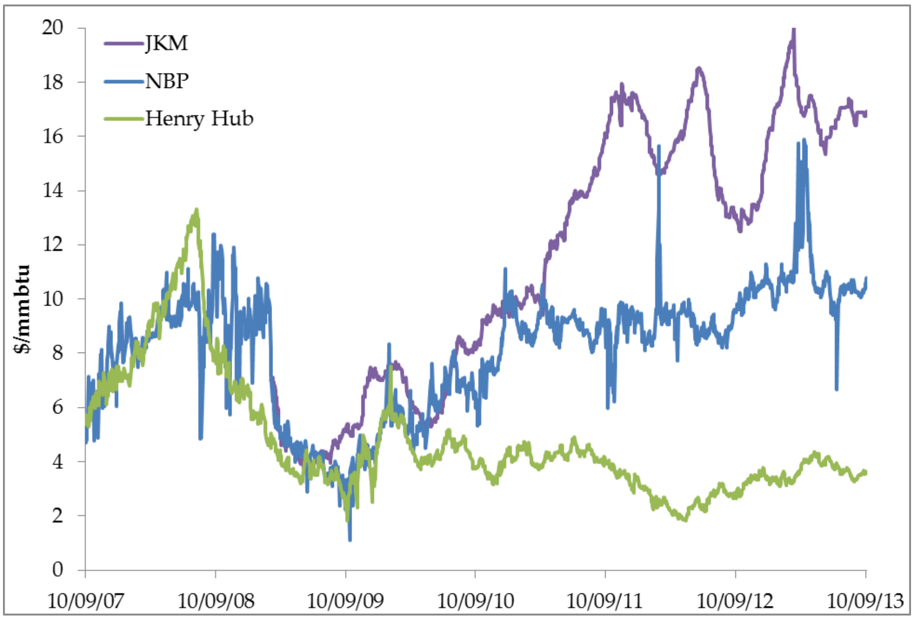

Figure 1: Spot gas prices in regional markets (USA – Henry Hub, UK – NBP, Asia Pacific – JKM)
Source: Henry Hub and NBP – Bloomberg; JKM - Platts

Overall, the US shale gas revolution produced improvements along several key dimensions:

1. Climate change mitigation – U.S. CO_2 emissions fell by 5.3% between 2010-2012, largely due to gas pricing coal out of the electricity generation mix (EPA, 2014)
2. Industrial and economic competitiveness – the so-called industrial renaissance has made it more attractive for energy-intensive industries to remain in or relocate to the United States (Deutch, 2011), for example the European chemical giant, BASF is shifting its production and research investment to the US to enjoy the shale boom (Barteau and Kota, 2014)
3. Energy security – dating back to the oil crises of 1973-79, the US had sought energy independence, but it was not until shale gas (and shale oil) that this longstanding goal was brought within reach.

Europe, by contrast, has been struggling to achieve its overarching policy goals of having secure, competitive and affordable energy. In the past few years, Europe has witnessed:

1. Energy price rises as a focus of political debate and the energy sector increasingly becoming a political battleground (Platt, 2014).
2. Industrial competitiveness hurt by not only the financial crisis but also by rising energy costs (European electricity prices are currently twice that of the United States and higher costs are having a significant impact on energy-intensive industries in particular (EC, 2014a)).
3. Its gas supplies at risk of disruptions due to repeated and increasingly more serious political crises along its eastern border in Ukraine.

4. Rising CO_2 emissions in some EU member states (e.g., Germany, see Wagstyl, 2014) – in the U.S., cheap gas has replaced coal in power generation leading to cheap US coal exports to Europe that displace gas in electricity generation.

In response, shale gas is increasingly seen as an important means of improving Europe's energy security and competitiveness (Stevens, 2010; EC, 2014b)). In the next sections, we provide a review of the existing literature on shale gas development in Europe and discuss various gas supply options available to Europe, and their advantages and disadvantages relative to shale gas from economic and political perspectives. We conclude by outlining future research to better understand shale gas production economics.

2. Literature review

Most published studies on shale gas in Europe address either the potential macroeconomic and energy market impact of shale gas production or relate to the environmental and safety considerations of using hydraulic fracturing stimulation (fracking) (Kavalov and Pelletier, 2012). Other studies focus on general market analysis and the geopolitical implications of a possible shale gas revolution in Europe. We review these studies in turn, starting from studies that explicitly discuss and analyse the potential shale gas cost and production economics.

Geny (2010) carried out a comprehensive analysis of European shale gas covering the success factors underpinning the US shale revolution and the challenges faced by the European gas industry in replicating the US experience. This analysis concluded that cost of developing shale gas plays in Poland and Germany is roughly two to three times higher than in the US and that they are on the high end of the cost range compared to conventional gas in Europe. As one of the first analyses of European shale gas it is understandable that important factors such as co-production of liquids were not taken into account in the costing analysis. Indeed, in the current environment of relatively low gas prices in the US, shale gas production levels are mainly sustained by the production and processing of natural gas liquids (NGLs), which are a by-product of shale gas production. The effective break-even price for shale gas is thus lower for shale wells with a higher share of NGLs. Further, relying on single point estimates (averages) for costing of shale gas such as surface and subsurface capex, field depth etc. does not necessarily reflect the economic nature of hydrocarbon production from shale formations (as discussed below). Similar to Geny's (2010) study, Rogers (2011) analyzed the success factors underpinning the US shale boom whether similar developments might be expected in Europe. Rogers (2011) stressed the importance of raising service industry capabilities in Europe; however, no economic analysis (such as potential shale gas break-even prices in Europe) was carried out.

Poyry published two economic analyses of the European shale gas and its impact on economy and energy markets. The first was commissioned in 2011 by the UK's energy regulator, Ofgem, on the impact of unconventional gas on Europe (Poyry, 2011). The second was published in 2013 on the macroeconomic effect of

European shale gas production, and commissioned by the International Association of Oil and Gas Producers (Poyry, 2013).

The Poyry (2011) report presented two extreme views regarding the economics of shale gas production – the contrarian and the industry views – which express either scepticism (cost of production and shale reserve quality) or optimism (great prospects for improvements and learning-by-doing and hence cost reduction) regarding shale gas economics in the US. For their analysis of impact of European shale gas development on GB energy markets, they have relied on cost assumptions made by Geny (2010). Further, in 2013, Poyry in collaboration with Cambridge Econometrics (Poyry, 2013) conducted another analysis of macroeconomic effects of European shale gas production for the International Association of Oil and Gas Producers. The costing of shale gas in Europe for this analysis was based on cost assumptions made by Geny (2010) and the European Commission's Joint Research Centre (JRC) (2012). The EC JRC (2012) report on unconventional gas production in Europe contains a detailed analysis of cost components to develop a shale gas well in Europe and gave a range of input data needed to calculate total capex for a particular shale well. It should be acknowledged that, to date, this is one of the most comprehensive publically available analyses of shale gas well costing. Based on these reports and cost assumptions, Poyry (2013) developed cost scenarios for European shale gas which depend on assumptions regarding technological progress and depletion of 'sweet spot' shale gas resource.

Similar to the study by Geny (2010), Poyry's shale gas reports (2011, 2013) do not include co-production of liquids in their analysis, which could, in some cases, reduce the shale gas cost significantly. The only studies that included liquids into their economic analysis of shale production are EC JRC (2012) and Saussay (2014). Saussay (2014) studied the potential profitability of shale gas in France using information on well productivity from the US Haynesville and Fayetteville shale gas plays. Similar to EC JRC (2012), Saussay (2014) considered co-production of liquids in the shale profitability analysis. Despite having access to publicly available statistical data on the well productivity of two shale gas plays in the US (Haynesville – 2432 wells, and Fayetteville – 4882 wells) the author preferred to use the average well productivity parameters to derive break-even prices and profitability under various scenarios instead of using distributions and hence probabilistic analysis.

Ionescu and Locatelli (2014) sought to analyse the economics of shale gas production using real options theory. Due to large uncertainties with regard to geology and productivity of shale gas as well as costs and regulation of shale gas in Europe, the application of real options seems appropriate. However, investment in shale gas production is not so "irreversible" since the cost of one well in Europe is roughly £10 million and hence drilling an exploration well to learn about the geology, environmental impact and negative externalities is negligible compared to a full scale investment programme required to produce a meaningful amount of gas in a particular lease area. For example, with an average initial production rate of a 6.2 million cubic feet per day and a decline rate of 75%, 920 wells at a total cost of £9.2 billion would be needed to sustain a production rate of just 0.3 trillion cubic feet (tcf)/year over a 20-year production horizon.

Other economic studies on shale gas in Europe focus on macroeconomic impacts of shale gas drilling in the UK such as employment, wages, gross value added etc (Regeneris Consulting, 2011; AMION Consulting, 2014). Bloomberg New Energy Finance (BNEF) submitted written evidence to the UK House of Lords (HoL) Select Committee on Economic Affairs enquiry into the economic impact of shale gas on UK energy policy. BNEF's written evidence is probably the most comprehensive analysis submitted to the committee and covers production economics of shale gas and estimated break-even prices. The HoL (2014) final committee report offers general discussions about the UK energy market, the US shale experience, shale gas potential in the UK, the regulation and environmental impact of shale and about the economics of shale gas. Similarly, the House of Commons' Energy and Climate Change Committee report on Shale Gas (HoC 2011) and written evidences submitted by energy experts does not reveal any serious analysis of potential production costs of shale gas in the UK or Europe.

Other publications on shale gas focus on the environmental and safety issues (e.g., MacKay and Stone, 2013) or political and geopolitical implication of a possible shale gas revolution in Europe (Gostyńska et al., 2011). de Jong et al. (2014) analyzed the implications of the American shale gas revolution on the stability of Europe's traditional energy suppliers. Other studies on shale gas and the potential geopolitical implications for Europe (Kuhn and Umbach, 2011; Johnson and Boersma, 2013; Bellelli, 2013; Spencer et al, 2014) have tended to focus on shale gas in the context of European environmental regulation, public acceptance, gas market regulation, energy security and geopolitical implications of shale development for Europe. The U.S. experience has also been extrapolated to other prospective regions such as China (Tian et al, 2014).

Two overarching conclusions stand out. Firstly, at the time of writing, rigorous analysis of the economics of shale gas production in Europe is very limited. Indeed, it is striking that, even in the United States, the peer-reviewed literature on shale gas production economics is scant, despite the extensive development of shale gas there. Kinnaman's (2011) review of studies on the impact of shale gas extraction in the US found: "*None of these reports has been published in an economics journal and therefore have not been subjected to the peer review process. Yet these reports may be influential to the formation of public policy.*" (Kinnaman, 2011). Since Kinnaman's (2011) review, the (peer-reviewed) US shale gas literature has grown. An excellent overview of shale gas production in the wider context of U.S. natural gas production overall can be found in Joskow (2013). Of particular note are studies by Gülen et al. (2013), Paltsev et al. (2011) and Medlock et al. (2011). Gülen et al. (2013) present one of the most comprehensive techno-economic analyses employing a probabilistic approach to study well economics of the Barnett shale. Paltsev et al. (2011) analysed the impact of shale gas production in the US, focusing on uncertainties in the cost and scale of gas resources, competing energy technologies and GHG emissions. The study employed a rigorous methodology for costing of gas resources (see Appendix 2C of the MIT (2011) study on the future of natural gas). Medlock et al. (2011), used an economic modelling framework to calculate break-even prices for major shale plays inside and outside of the US and assessed the implications of US shale gas revolution for national security and geopolitics. There are no studies for European shale gas as comprehensive as found in Gülen et al. (2013), Paltsev et al. (2011) or Medlock et al. (2011).

Secondly, the economics of shale gas in Europe appears to be marginal, and public acceptability, environmental risks and supply chain constraints (e.g., upstream service sector) might undermine its economics and hence replicating the US shale success would not be possible. Then, in light of the current Ukrainian crisis and a growing concern over dependency on Russian gas imports, the next section briefly outlines potential sources of gas supplies into Europe.

3. Shale Gas Economics 101

One way or another, all economic analyses of shale gas in Europe have used single point (average) estimates for the initial production and decline rates (productivity) of shale gas wells and/or the costs of developing these wells. Some studies supplement their research with scenario analysis (e.g., Poyry, 2013). In general, little attention has been paid to the issue of robustness of these point estimates. Further, using single values and scenario analysis has a fundamental flaw – an estimate that is based on the assumption that the average condition will occur is almost always wrong since the average of an outcome is most probably not the same as the outcome based on average assumptions (Savage, 2009). Using point estimates and scenario analysis would be sufficient if break-even prices are linear in input parameters, such as well productivity and costs. However, no study of shale gas production has looked into this very basic question. Hence there is at least a need to do a stochastic analysis of break-even shale gas prices to check the inherent assumptions of all the studies that use point estimates – is shale gas break-even price linear in well productivity and costs?

Further, applying average well productivity and/or costs ignores a crucial fact that only a small fraction of wells drilled are critical to the overall economic success of any shale gas lease. The operator's objective is therefore to understand why certain wells succeed and how to replicate the success for subsequent wells. In other words, economic analyses that rely on single point estimates do not reflect the reality of shale gas production economics. A more robust way to treat uncertainties surrounding shale gas economics is to conduct stochastic analysis of its main components (well productivity, cost along the value chain, drilling productivity etc.) (Gray et al., 2007; Jacoby et al, 2012). For example, 10% of wells in the Barnett shale in Texas could be developed at a break-even price of less than $4.25/mmBtu. The production economics of these wells are driven by very high well productivity and low investment costs.

Another consideration in the production economics of shale is the usage of long-run marginal cost curves. For example, the Poyry (2013) study uses cost scenarios and a linear programming gas market model (cost minimization to meet certain demand level, i.e., perfectly competitive gas markets) to assess market impact of shale development in Europe. By using marginal cost curves they assume that shale gas producers have perfect foresight and, in particular, knowledge of where the sweet spot is, i.e., the most prospective areas with high concentrations of shale gas. This is an inherent problem of using marginal cost curves for shale gas economic analysis.

The concept of (increasing) marginal cost curves is applicable to conventional oil and gas analysis because once the exploration phase (where most risks lies) is completed and prospective basin and fields are identified, producers would normally drill and deplete the cheapest field first. That is, the risks and uncertainties associated with conventional gas production are minimal compared to shale gas production. Using marginal cost curves for conventional exploration is acceptable since the curve assumes the least cost field is developed first and so on. Shale gas extraction is much more complex and well productivity varies greatly even within the same shale formation. For example, gas on the east side of the Barnett Shale is dry, but 100 miles to the west, there are abundant liquids, thereby reducing production costs (Pickett, 2010). Even within the same shale formation (e.g., Barnett and Haynesville) well productivity can vary by a factor of twenty (authors' estimates based on Drillinginfo Database).

Using a single point estimate (average) for shale gas costs in economic impact analysis is, therefore, not helpful and misses an important economic dimension of shale gas development – ***the highly stochastic nature of shale gas production***. The stochastic nature of shale gas production comes from a combination of: (i) poor understanding of geological conditions in prospective shale areas – as noted, geological conditions can vary greatly, even over short distances; and (ii) the complexity of the shale gas production process since any optimization of the process will be a function of geology, supply chain, project management, etc. In other words, even two shale wells with identical geological parameters could have completely different production profiles due to the greater complexity of shale gas production compared to conventional gas production. The importance of NGLs to the production economics adds another layer of complexity and, taken together, all of these complications would add significant variability to the break-even prices of shale gas from one lease area to another.

In general, using single point estimates as was done in previous studies would yield the expected result that shale gas is more expensive than conventional gas, at least for shale gas outside the U.S.. The most important economic question with regard the shale gas production economics, however, is to identify and understand the properties of the distributions governing shale well economics and the extent to which one can transfer the knowledge and experience gained developing the best (cheapest) wells to other areas and leases.

The highly stochastic nature of shale gas production has another important implication – it should generally favor small exploration and production companies with greater flexibility and higher risk appetites. Indeed, the shale gas revolution in the US has been led by small oil and gas independents (Chesapeake Energy, Continental Resources, Devon Energy, Occidental Petroleum etc.) and not by traditional majors (such as ExxonMobil, Shell, or Chevron). Put another way, oil majors, being more risk averse than smaller independents, operating in the same (risky) environment would take a more cautious investment strategy (Sandmo, 1971). However, risk-taking is essential for successful shale gas production due to a large potential in learning and cost reduction – improvement in geological knowledge and operational efficiency. For example, the first 60 wells drilled in the US Haynesville shale deposit were uneconomic and it took 100 wells to demonstrate that flow rates could reach economic quantities over a wide area of the region (Navigant, 2013). For one operator in the Marcellus shale, the drilling and completion (D&C) cost for the first well was $7.5 million while the D&C cost for the fourth well was $5.6 million (or 25% reduction). The reduction was due to data acquisition and well evaluation, improvement in drilling and completion efficiency (Talisman Energy, 2009). For each additional well drilled in the Barnett shale between 1987 and 2014, the average initial production rate (one of the metrics for well productivity) was increased by 0.061 mcf/day (authors' own estimates based on Drillinginfo Database).

Uncertainties in well productivity and rapid decline rates would discourage shale gas producers from selling gas under long-term contracts and encourage them to deliver gas directly to hubs or sign short-term contracts with buyers, since it would be too risky for shale producers to guarantee a fixed stream of gas flows for longer periods of time (e.g, >five years) (see Hughes, 2013 for a discussion of such concerns in the U.S. context). Large quantities of shale gas flooding the markets would depress spot prices in Europe and add liquidity. This, in turn, might affect gas pricing of European traditional suppliers, like Russia, since all traditional oil-linked long term contracts are now partly linked to hub prices. Depending on the price differential between long-term contract prices and hub prices this would also trigger another wave of price renegotiations, at least for Russian gas contracts.

In particular, access to the pipeline network and cost of access are important factors since the economics of shale gas In Europe will be marginal compared to conventional resources. There is a striking difference between the US and Europe in terms of gas market organization – in the US, there is a well-functioning, competitive, liberalized gas transportation market, which is a pre-condition for a liquid, competitive wholesale gas market (Henry Hub is the most liquid and competitive gas trading hub in the world) which has helped facilitate the U.S. shale gas revolution (Makholm, 2012; Hunt, 2008). By contrast, in Europe the pipeline network is managed and overseen by national transmission system operators.

Liquid wholesale markets are important not only for pricing purposes but also for hedging – since shale gas producers in Europe are highly unlikely to lock themselves into traditional long-term contracts they would require financial hedge instruments such as gas forward and futures contracts (see e.g., Ludwig, 2011). Since shale gas production would be most efficiently led by smaller independents, their risk profile is concentrated on production and traditional hedging such as moving along the gas value chain (e.g., downstream) to safeguard their position would destroy their competitive advantage relative to integrated oil and gas majors. Hence, they would require financial risk hedging tools to shield their production positions. European gas hubs are not so well developed – Henry Hub is at least six times more liquid than the UK NBP, the most liquid European trading hub, (as measured by relative churn ratio of the two hubs).

4. Shale Gas Resource Assessment for UK and Continental Europe

In the last few years, the British Geological Survey (BGS) has released a series of detailed studies of shale gas resources in the UK (Table 1). In 2013, BGS developed estimates of total gas in-place for the Bowland Shale of 1329 trillion cubic feet (tcf). More recently, BGS has produced detailed estimates for the Jurassic Weald Basin and Carboniferous Midland Valley of Scotland. According to these estimates, the Weald Basin has no significant gas resource and contains 4.4 billion barrels (bbl) of oil in place, whereas the Midland Valley of Scotland might contain 80.3 tcf (central estimate) and 6.0 billion bbl of oil in place.

Table 1: UK Shale Gas Resource Assessment by BGS (in trillion cubic feet or tcf)

	Lower limit	Central estimate	Upper limit
Bowland Shale (England)	822	1329	2281
Midland Valley (Scotland)	49.4	80.3	134.6
TOTAL	871.4	1409.3	2415.6

Source: BGS various reports, see BGS website: http://www.bgs.ac.uk/research/energy/shaleGas/home.html

The BGS estimates characterize the gas resource (or gas-in-place), which represents their estimate of the volume of shale gas present in the formation, but not the volume of gas that it might be possible to extract. The volume of gas that could be produced (reserves) will depend on economic, technological and social factors. The BGS estimates look rather optimistic compared to the U.S. Energy Information Administration's assessment (EIA, 2013) of 141 tcf of risked shale gas in-place and about 25 tcf of technically recoverable shale gas, implying a recovery factor of 17.5%. The amount of risked-gas in place is estimated in the EIA report by factoring in the formation's success factor, which for the carboniferous shale formation in the UK is 21%, meaning that according to the EIA, the UK's risked shale gas in-place is 671 tcf, or just over half of BGS's central estimate for the Bowland shale formation of 1329 tcf.

The conclusion of the overall EIA (2013) assessment of European shale gas plays is that total technical recoverable shale gas in Europe (Table 2) could cover roughly 38 years of EU gas consumption (15.5 tcf/year in 2013, according to BP, 2014). However, a more important insight from these analyses is that uncertainties over how much shale gas can be exactly extracted in Europe is extremely high. For example, the difference between BGS' lower and upper limit is up to three times. EIA (2013) estimates for Europe are even wider if one compares the amount of original gas-in-place (GIP, Table 2) with the amount of technically recoverable (TR) shale gas (that EIA's specialists conjecture) – 25 to 1 for the UK assessment, for example. This extremely high spread highlights EIA experts' perception about the level of geological, economic and (most importantly) technical condition of shale gas exploration and development in Europe. However, as noted in the previous section, the nature of this uncertainty should not in itself be a barrier to small (entrepreneurial) exploration and development companies entering the market. The major questions from an economic perspective are over the extent of regulation, market access and liquidity, especially in Central and Eastern European gas markets (such as Poland).

Table 2: European shale resource gas assessment by EIA (in Trillion Cubic Feet or tcf)

Region	Basin	Formation	GIP*	Risked GIP	TR
UK	N. UK Carboniferous Shale Region	Carboniferous Shale	600	126	25
	S. UK Jurassic Shale Region	Lias Shale	25	8	1
Spain	Cantabrian	Jurassic	105	42	8
France	Paris Basin	Lias Shale	48	24	2
		Permian-Carboniferous	2081	666	127
	Southeast Basin	Lias Shale	206	37	7
Germany	Lower Saxony	Posidonia	130	78	17
		Wealden	4	2	0
Netherlands	West Netherlands Basin	Epen	209	94	15
		Geverik Member	113	51	10
		Posidonia	16	7	1
Sweden	Scandinavia Region	Alum Shale	163	49	10
Denmark		Alum Shale	663	159	32
Poland	Baltic Basin/Warsaw Trough	Llandovery	1330	532	105
	Lublin	Llandovery	219	46	9
	Podlasie	Llandovery	225	54	10
	Fore Sudetic	Carboniferous	594	107	21
Lithuania/ Kaliningrad	Baltic Basin	Llandovery	75	24	2
Ukraine/ Romania	Moesian Platform	L. Silurian	218	48	10
Romania/ Bulgaria		Etropole	822	148	37
TOTAL			10635	3027	590

Note: * GIP: Gas in-place; TR: Technically Recoverable; GIP have been derived by dividing Risked GIP by shale play success factors as reported in EIA (2013), Attachment B.
Source: EIA (2013)

5. Shale Gas Politics in Europe

In light of the Ukrainian crisis of 2014, energy security concerns have been driven further up the European agenda taking along shale gas. Figure 2 shows the status of European countries' dependence on Russian gas and annual gas consumption to give a sense of the energy security driver and the size of the domestic market. In spite of moderately sized reserves, a number of EU member states have chosen to effectively shut down exploration in the face of widespread public and NGO opposition. Several of Europe's largest gas markets including France, the Netherlands and Germany, which together constitute 35.2% of EU28's gas market have various forms of moratoria on shale gas exploration. Coincidentally, these include not only some of the largest markets in Europe but also some of the most liquid (e.g., TTF in the Netherlands). Although these countries could potentially support shale gas production in an economic sense, concerns over environmental risks dominate and energy security has not yet risen to a level that would change policy.

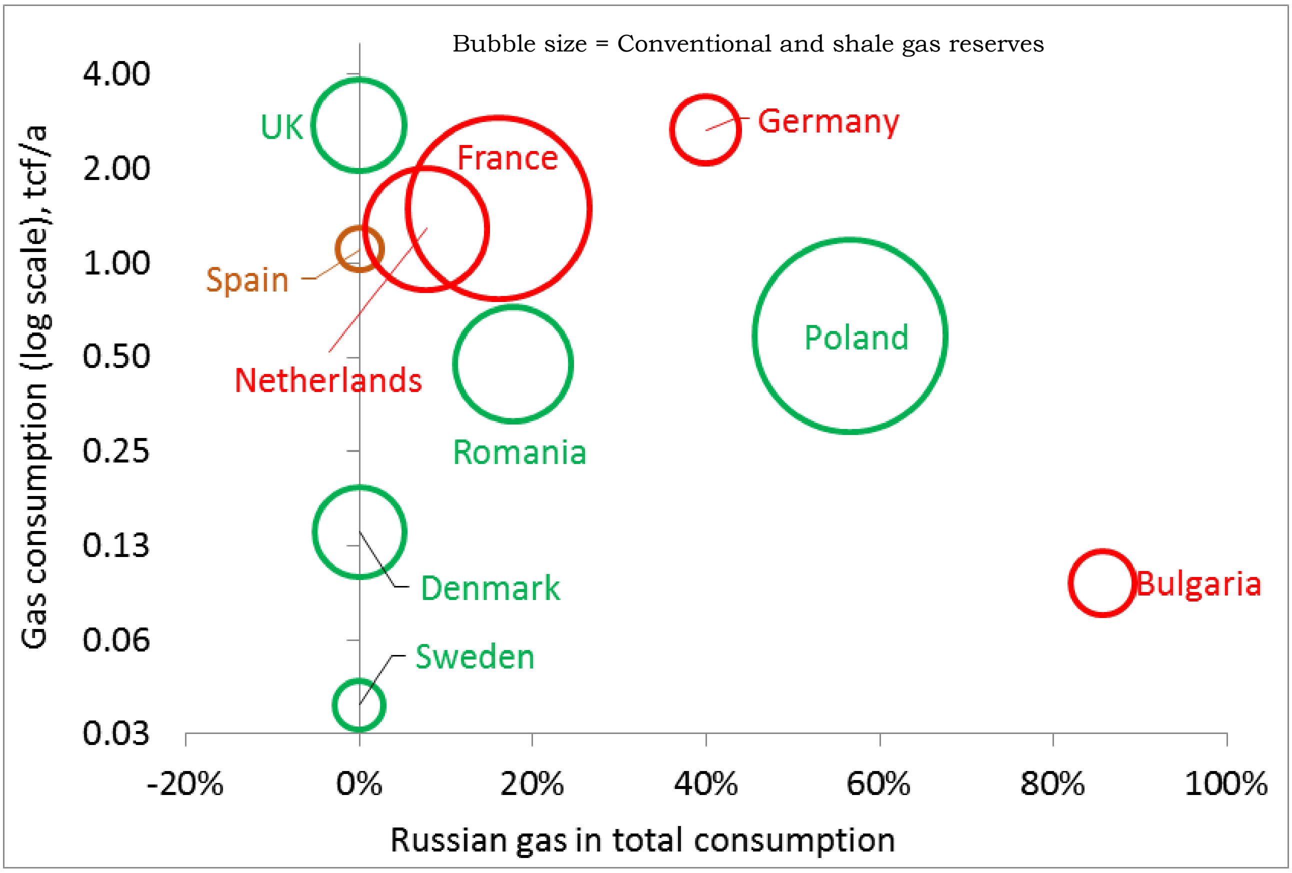

Figure 2: Gas Import dependence and national shale gas exploration status
Note: Green – shale gas exploration is allowed; Red – currently moratorium on shale gas exploration; Orange – regional shale gas moratorium; Data for all EU countries are as of 2012; Gas consumption is reported for year 2012 in trillion cubic feet[2];
Source: authors' calculations based on IEA (2013), BP (2013), EIA (2013)

On the other hand, energy security is a major driver of shale gas development in such countries as Poland, Baltic States, and some central and southeastern European countries. However, these markets are generally small compared to northwestern European markets, are the least liberalised and gas pricing remains regulated or dominated by oil indexation mechanisms. According to the IGU (2013), for example, in Poland, 50% of gas is still linked to oil products prices, 35% is priced based on gas-on-gas competition and 15% is regulated. In such an

[2] The conversation factor is one billion cubic meter equals to 0.0353 trillion cubic feet of gas, according to BP (2013)

economic environment, the scale and pace of shale gas production could not begin to replicate the US experience.

The UK seems to be in a better position to develop shale gas. It is the largest and most liquid market in Europe. Although, the UK does not depend on Russian gas at all (i.e., no physical deliveries), it does depend on Norway, gas from the continental Europe and overseas LNG, which, has become an increasing concern for British policy-makers. The UK government is supportive of developing shale resources, particularly supporting private investment with tax incentives (HM Treasury, 2013).

As evidenced by the national moratoria, another major challenge for firms (and governments) is the need for a social license to operate for shale gas exploration in Europe. Overall, support for shale gas exploration is low and in many areas there have been very strong local opposition. In a survey of all 28 EU member states, Poland was the only member state where a sizeable minority (32%) thought that unconventional fossil fuels, such as shale gas, should be prioritised in national energy policy, whereas that figure ranged from 3%-11% for all other member states (Eurobarometer, 2013). Similarly, almost three-quarters of respondents (74%) claimed they would be very concerned or fairly concerned if a shale gas project were to be located in their neighborhood and again, only in Poland did less than half of respondents express such concerns. Only 16% of Poles claimed to be very concerned compared to 54% of French and 50% of Bulgarian and German respondents. Studies in the UK have found growing awareness of shale gas with net support declining over time, and varying from +20% to -10% depending on the framing of the question (O'Hara, et al 2014; Opinium Research, 2014).

Public support for shale gas activities across Europe is quite weak for a number of reasons unrelated to outside forces – population density, lack of familiarity with onshore oil and gas extraction, the strength of local and national NGOs in many countries, concerns over various risks associated with water and air pollution, earthquakes, traffic and noise (Moore, 2012). Perhaps most importantly, unlike in most of the U.S., in Europe the state rather than the landowner has rights to the subsurface and so the potential for landowner compensation (and hence support) is much lower.

The lack of progress of the shale gas industry in Europe has led to charges that failure can be attributed not to problems of economics, geology or public acceptance, but rather to lobbying efforts by the indigenous coal industry, competing gas import and Russian pressure (Smith, 2012). Russia obviously stands to lose both economically and politically if shale gas is developed at scale in Europe (Kropatcheva, 2014) and Russia has generally taken a dim view of unconventional resources (Ocelík and Osička, 2014). There have been concerns voiced that Russia is applying pressure on multinationals not to invest in European shale gas operations, with ExxonMobil pulling out of Poland cited as an example (Tucker, 2012). Others have claimed to see Russian influence in the Bulgarian moratorium and the Greenpeace-led protests in Pungesti, Romania (Jones, Chazan, and Oliver, 2014). The spectre of Russia supporting European NGOs to oppose fracking has been cited by Tucker (2012), and most recently, by the NATO Secretary General Anders Fogh Rasmussen, in remarks at Chatham House (Johnson, 2014). Such claims have angered many leading NGOs, such as Friends of the Earth and Greenpeace, who have long been hostile to the Russian government on other policies and who are outraged at being portrayed as puppets of President Putin. Even senior officials in potentially sympathetic governments, such as Poland, have argued that the problem is not the lack of political will, but rather "it is all about geology" (Harvey, 2014). Economic considerations are barely even mentioned in the public and political debate.

6. Conclusions

Most publicly available analyses of shale gas in Europe focus on either macroeconomic and energy market impacts or on the potential cost of developing shale gas in Europe (Weijermars, 2013). In so doing, most economic analyses assume averages for such important parameters as well productivity and drilling performance. The conclusions of these analyses have been that economics of shale gas in Europe is marginal, and that environmental and other constraints (e.g., upstream service sector) further undermines its economics and hence shale gas in Europe would be developed on, at best, a modest scale. However, to date, no studies have focused on the essence of shale gas economic analysis – the highly stochastic nature of shale gas production. A probabilistic analysis of shale gas production will need to capture the properties of the distribution of shale well economics and the extent to which firms can replicate their experience in developing the best (cheapest) wells to other areas and leases. Based on our analysis, drawn largely from basic principles rather than a detailed basin-by-basin assessment, we conclude that due to the stochastic nature of shale gas and steep decline rate, having a liquid and competitive domestic gas market is an essential precondition for successful shale gas exploitation. In this regard, if countries in Central and Eastern Europe (such as Poland and Romania) truly want to be able to develop shale gas, then it is not enough to have public and political support based on security of supply concerns – ultimately, their governments should liberalise and deregulate their gas markets.

Given the recent developments in Ukraine, European policy makers seem to favor developing shale gas as an option for Europe to diversify gas imports away from Russia since other suppliers (e.g., overseas LNG, Middle East and North Africa) are not very promising in the short to medium term. A more problematic question, which affects both the economics of conventional gas supply options to Europe as well as European shale gas is the wider future of natural gas in Europe over the 2025-2030 time horizon. Diversification away from Russia requires large investment in economic and political capital to develop shale gas and to develop infrastructure outside Europe. All of these considerations point to the likelihood that gas will not be cheap in Europe going forward and hence indigneous European shale gas may seem an attractive option. But to develop this resource successfully, Europe will not just need to deal with concerns over the social license to operate by addressing public concerns, but must work towards the completion of the single gas market. EU member states should make sure that their gas markets are liquid, deregulated and contestable (or at least develop policies and regulations to encourage market entry).

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