Economic effects in the UK periphery from unconventional gas development: Evidence from Wales

Calvin Jones*, Max Munday*, Meng Song* and Neil Evans**

*Welsh Economy Research Unit, Cardiff Business School, Colum Drive

Cardiff CF10 3EU. UK

Jonesc24@cf.ac.uk

Mundaymc@cf.ac.uk

SongM1@cf.ac.uk

**Regeneris Consulting, Faulkner St, Manchester M1 4DY

N.evans@regeneris.co.uk

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Introduction

The paper examines the potential regional economic benefits of the development of unconventional gas. [1] As the global demand for energy continues to grow, the potential for exploiting unconventional gas has attracted interest (Measham et al., 2016). Technological developments have made it feasible and profitable (in some places) to exploit unconventional fuels such as shale gas and coalbed methane (CBM). Bilgili et al. (2016) have argued that much of the energy economics literature has focused on conventional energy such as coal, oil and natural gas and there is less clarity on how developments in the field on unconventional gas might contribute to regional economic development prospects. Whether the exploitation of unconventional energy generates economic benefits such as income and employment growth remains controversial, and the magnitude of such effects varies greatly between studies (Fleming et al., 2015a). Kinnaman (2011) argues that research on the expected economic impact of unconventional gas tends to overestimate the economic benefits. Fry et al., (2015) echo the conclusions of Kinnaman showing that few studies empirically explore the full range of effects resulting from local shale gas development, and Hoy et al (2017) in the US shale gas case also argue that studies of impacts of shale gas development can lead to 'gross overestimates' of economic impacts. There is a further problem in that much of the analysis in the UK (and Europe) has drawn inference on potential economic effects by examining the US case, and with only a few studies covering other countries such as Australia and China (Krupnick et al., 2014). More generally, drawing inference from effects observed in the US ignores its very different institutions, firms, geology and structures (Kinnaman, 2011).

Unconventional gas exploitation in the UK is at an early stage, but with research already suggesting that the contribution of UK-produced onshore shale gas to energy markets and economic growth could be very modest in comparison with the US case (see for example, Cooper et al.,

[1] We take unconventional gas here to cover shale gas (although oil is also relevant but less common in Wales), coalbed methane (CBM) and gasification. Whilst shale gas and CBM refer to specific fossil fuels, gasification refers to one particular technique for extracting product gas including methane. The focus of the paper is shale gas and CBM.

2018). However, there is still scope for an assessment of the likely effects of sector expansion on more regional economies.

Wales (UK) represents a particularly interesting lens through which to examine the expected effects of unconventional gas developments. The region has found it difficult to embed resource and energy industries into the local economy (see Bryan et al., 2017), and with many of the economic benefits leaking outside of the region (Munday et al., 2011). For example Bryan et al., (2017) examined how different electricity generation technologies worked to support direct employment in Wales through plant operations, but also employment supported in the supply chain to power generation plants and employment supported in the development and construction process. The Welsh supply side limited the economic opportunities from new power generation development, and with much of the economic opportunity benefiting firms outside of the region, and with the conclusion made that key decisions on capital investment were made externally, developers and managing contractors were based externally, and then with the risks and rewards of new energy development internalised elsewhere. An issue explored in this paper is whether an expansion of capacity in unconventional gas production in Wales will be any different from recent rounds of resource and energy investment in (and for) the regional economy.

The paper then aims to make a contribution in the following areas. First, much of the analysis of the potential economic effects of unconventional gas in the UK has been developed at national level, with limited consideration of effects and constraints on development at smaller geographies. We seek to address this limitation, focussing on local/regional effects in terms of employment and income support, rather than more complex and holistic energy-supply side impacts that imply price and displacement effects. Second, through a series of development scenarios, the paper highlights how constraints in the regional *economic* supply side place severe limits on how the expansion of unconventional gas capacity might create new opportunities in the peripheral Welsh economy. Third, we point to the factors that may either enhance or restrict how new energy and resource investments can work to bolster local economic prospects in more peripheral parts of the UK economy. This leads to policy implications for regions in the UK that are seeking to capitalise on energy and resource investments.

The remainder of the paper is structured as follows. The second section examines prior research on the economic effects of unconventional gas, and the third section provides background and the method employed to examine the expected effects of unconventional gas development in the case economy. The fourth section reveals the results from the scenario analysis. The final section contains some discussion and conclusions.

The regional economic effects of unconventional gas

One framework underpinning research on the economic impact of resource extraction is based on Corden and Neary (1982). They propose that as an energy extraction sector grows, the demand for labour increases, pushing up wages and production costs for non-tradable and tradable sectors and increasing demand for other products. As a result, the non-booming export sectors suffer due to higher labour costs and real exchange rate appreciation, and become less competitive in the world market (i.e. Dutch Disease). The result here can be a booming energy sector increasing costs for other non-energy sectors and a resulting contraction in these sectors (Jacobsen and Parker, 2014). Fetzer (2014) observes that in spite of the rising labour costs in the shale oil and gas boom in the US, there is no Dutch Disease contraction in tradable goods sectors, but the non-tradable goods sector contracts. Previous work, together with an examination of exports (see Bryan et al., 2017) implies that even for a small and energy-rich but 'developed' economy like Wales, economic activity and exports are sufficiently diverse to rule out Dutch Disease. However, an increase in unconventional gas activity might increase total income and decrease poverty by employing previously unemployed people, or by paying higher wages to attract workers from non-booming sectors. In addition, drilling on private land will require energy companies to pay monies to private landowners, and tax to public sectors. This could improve public services and investment to benefit a wider range of communities (Weber, 2012).

Notwithstanding the above the findings on the economic impacts of unconventional gas on economies is a contested area, and with this partly related to the exact terms of reference of studies particularly in geographical and industrial terms. Bilgili et al. (2016) find that shale gas production has a significant and positive effect on gross domestic product (GDP) in the US as a whole, but Cosgrove et al. (2014) observe that the impact from shale gas development on employment and income is only significant at industry level, but not across the entire economy. For example, Weber (2012) selected three areas, Colorado, Texas, and Wyoming that had experienced considerable shale gas production since the late 1990s, and revealed only modest economic benefits. Similarly, DeLeire et al. (2014) find significant employment effects from shale gas extraction (Marcellus shales in the US), but no income benefits on the county where a well is located (see also Hartley et al., 2015). A recurring issue in studies is leakage of monies from mining areas. For example, Fry et al (2015) in a study of shale gas developments centred on Denton in Texas revealed that local residents gained relatively little of the total value of the extracted resource with primary beneficiaries being non-local mineral owners. Non mineral owning residents drew few direct financial benefits and few indirect financial benefits. Similarly, Weinstein et al., (2018) observed economic multiplier effects of investment in gas and oil industries in the US, but show that this might work to undermine future growth prospects for affected areas. For example in-migrant workers may exit and the resource-rich communities are left with a declining industry. They also show the propensity for a large share of shale gas industry earnings to leak from the areas where the mining development takes place. The leakage and long term development issue is also revealed in research by Kelsey et al. (2016). They explain why the economic impact of an unconventional energy boom may not translate into long-term development with much of the employment effect occurring during the drilling phase, and with many of the new workers from outside a region moving to other drilling locations following this phase. Additionally, at the initial stage of an energy boom, government spending will surge to spend on new infrastructure to support energy exploitation. However fiscal stress will appear after the boom when the infrastructure needs to be maintained, and while there are fewer residents to pay for it, as mobile workers will have left the region.

A series of other studies also examine indirect and spillover effects resulting from unconventional gas. For example, Paredes et al (2015) examined Pennsylvania Marcellus shale gas developments and found little evidence in terms of local indirect or induced income effects, and concluded that care was needed from local decision makers who may might be tempted by the promise of economic spillovers effects from shale developers. Tsvetkova and Partridge (2016) report significant positive spillovers of the shale boom to related non-traded sectors, but small negative externalities for traded goods. They summarise that the controversial empirical evidence is influenced by several factors including sample, empirical model and timeframe, making it challenging to generalise the findings of economic impact of unconventional energy (see also Fleming et al. 2015b; Komarek, 2016).

To conclude, the findings on economic benefits (and socio-environmental costs) from unconventional gas utilisation are controversial and difficult to generalise. In the UK case there is a slowly emerging regional evidence base of the expected effects of shale gas fracking, but inevitably the sparsity of shale gas operations at anything other than experimental scale in the UK makes conclusions difficult. Moreover making generalisations about economic effects from studies in the US is difficult, as our analysis will show. Notwithstanding there is a challenge to better understand what the effects of development could be particularly in areas with persistent socio-economic problems, and where such shale development could be viewed as a development opportunity.

3. Background and method

In the wider UK the interest in the scope of unconventional gas is associated with the size of the potential resource. The UK has abundant shales at depth, although their distribution is not fully understood. For example, the UK Department of Energy and Climate Change (DECC, 2013) revealed 2010 information from the British Geological Survey on estimated yields from three main UK plays. This suggested across these three areas (i.e. UK Jurassic shale pay – Wessex Basin; UK Carboniferous – Upper Bowland and UK Cambrian) that the joint yield could be in excess of 2.4 trillion cubic feet (tcf), although with much of this focused in the Upper Bowland (see also Regeneris et al., 2015).

There is some consensus that developments around unconventional gas (particularly shale gas resources) will not have the same effects in the UK as has occurred in the US, and with this linked to a series of geographical, institutional and regulatory factors (see Kinnaman, 2011). Then in spite of emerging evidence on the scale of the resource, shale gas drilling in the UK is very much at evolutionary stages, although there are a series of operational CBM facilities. In the case of shale gas in the UK, the end of 2016 had seen no commercial level drilling but with two planning applications in Lancashire and North Yorkshire in process (Delebarre et al., 2017). By the Autumn of 2018 activity is still limited with a small number of 'active' fracking sites in terms of either drilling planned, exploration and testing, but none in full production. Attention (at the time of writing in September 2018) is focused on the Cuadrilla Resources site near Blackpool, where the firm has drilled two shale gas appraisal wells. The company has gained consent to frack one of the wells drilled at its Preston New Road site in Lancashire, and has plans to apply for consent to frack the second well (Lewis, 2018). Third Energy at its site at Kirby Misperton in Yorkshire is waiting for government approval to start test fracking at its Kirby Misperton site in Yorkshire.

The case in this paper is focused on Wales. Wales is a devolved part of the UK and is best characterised as a small open economy. For example in 2016 Welsh total gross value added was around £59.6bn which was just 3.4% of the UK total, and with the region containing around 4.4% of the UK employment, and 4.7% of UK population in 2017 (3.125m people). While Wales is a devolved region, energy policy has historically been largely reserved to the UK parliament. While Welsh Government in policy documents has in the past argued that natural gas use should be part of the process towards a low carbon transition (Welsh Government, 2012) there has been little explicit support for shale gas development.

Recent activities in Wales need to be understood in the context of a complex UK regulatory environment around shale gas. The Department for Business Energy and Industrial Strategy (BEIS) (formed from a merger of DECC and Department of Business Innovation and Skills (DBIS) in July 2016) has overarching responsibility for setting energy and climate change mitigation policies. DECC had previously issued Petroleum and Exploration Licenses for Welsh areas (PEDLs) giving rights to prospect for different petroleum types in a given grid area. The UK Oil and Gas Authority (OGA) is an executive agency of BEIS (previously DECC) and works to license and regulate exploration and development of UK onshore oil and gas resources. The OGA issues well consents, development and production consents. The Environment Agency (EA) is the English environmental regulator for onshore gas operations, but its functions in respect of Wales were taken over by Natural Resources Wales in 2013. Moreover, more steps have been taken in respect of the devolution of responsibility for onshore petroleum licensing and regulation to the Welsh Government through the Wales Act 2017 (Onshore Petroleum) (Consequential Amendments) Regulations 2018. This effectively transfers regulatory and licensing powers over onshore petroleum development to Welsh Ministers as from October 2018 meaning a takeover of duties previously undertaken by the UK Oil and Gas Authority. Welsh Government in July 2018 issued a consultation document to seek views on future devolved policy towards petroleum extraction

(Welsh Government 2018, Petroleum Extraction Policy in Wales). This requirement, in part, followed from Welsh Government directions in February 2015 issued to local authorities in Wales stopping planning permissions for any unconventional gas development involving hydraulic fracturing without explicit approval from Welsh Ministers (see Welsh Government, 2015). This resulted in an effective moratorium on hydraulic fracturing. The 2018 Consultation then occurs in the context of further devolved regulatory powers to the Welsh Government and with this consultation seeking stakeholder feedback on proposals in respect of the regional government position on further petroleum licensing in Wales and in terms of their stance on hydraulic fracturing.

A number of firms have Petroleum Exploration and Development Licenses (PEDLs) in both North and South Wales and Regeneris et al. (2015) reported that in Wales at that time, two CBM wells were planned, fourteen had planning permission and 6 had been drilled. Some firms also have specific applications for shale gas exploration but with very limited activity to date. The last round of PEDLs closed during 2015. By August 2017 there was still limited Welsh activity with four proposed developments with planning consent (approved 2012-16) and environmental permits (granted 2015-16), but with a focus on exploratory drilling as opposed to production. One of these developments related to oil with the remainder focused on CBM. Two additional CBM sites had gained planning permissions but were without environmental permits in August 2017. In only one further planned case at Margam in South Wales were there early plans for 'larger scale' CBM production. So in conclusion to date, progress has been modest, and focused more on CBM. Moreover the period 2017-18 has seen very limited further development with respect to shale gas and hydraulic fracturing because of the current consultation around how far Welsh Ministers will permit any further development (see Welsh Government, 2018).

The exploration and production of unconventional gas in Wales (as in the UK) depends on geology, changes in regulatory regimes and market conditions (see also Sarhosis et al., 2015 specifically on the economic potential of CBM in Wales in the context of power generation). Only with improved geological and geophysical understanding of the target formations will the industry have greater confidence over whether Wales represents an attractive area for investment.

However, shale gas could present a significant economic opportunity for Wales, given its potential large scale. Nevertheless, there has been no analysis of its potential economic impacts. In the assessment that follows, we present estimates of regional gross value added and employment (full time equivalent jobs) that might be supported following different development scenarios, and with the analysis focusing in on some of the factors that would constrain economic effects.

In what follows we describe the approach: the economic model employed, the development scenarios; and the data and local sourcing assumptions.

Economic modelling method

The assessment used the Input-Output (IO) Tables for Wales to estimate the gross value added (GVA) and full-time equivalent employment that might be supported in Wales from different shale gas/CBM development scenarios. The IO Tables present a detailed financial map of the economy for a particular time period, typically one-year, and shows the flow of goods and services between industries, consumers and government. As well as being an important descriptive tool, the Input-Output tables can be used for economic modelling and for impact assessment. Further description of the Welsh Input-Output project, its strengths and limitations, can be found in (Jones et al., 2010).

Figure 1 about here

Figure 1 illustrates the conceptual model used. The direct economic impact comes from the new economic activity at gas extraction locations. As operators demand Welsh labour, goods and services in pursuit of gas extraction, these supply chain impacts potentially extend for further spending rounds. Further economic activity is induced as workers in shale and supplying companies spend their wages, in part, in Wales.

Input-Output frameworks of this type have been commonly used in the US to assess the state-wide impacts of shale gas investments and are a valuable means of exploring the expected indirect economic effects occurring through regional supply chains supporting the exploration, extraction and long-term production of shale gas. However, this type of framework has some limitations.

First, it is very difficult to account for economies of scale, the changes in technological approach or the geographies and adjustment of supply chains (although our scenario analysis addresses this latter concern and see Miller and Blair, 2009 for the general limits of the Input-Output framework in these respects). Second, the likely industrial geography and evolution of shale extraction in the UK (or Europe) is an unknown. In the US, the industry is characterised by a far higher level of peripatetic capital than is the norm for other industries, driven by the short set-up and drilling periods and relatively short extractive life of shale wells (both gas and oil). In the US, there has been a need to constantly drill in new locations to maintain production, although this could in part be due to the economics of the sector in the US. Third, in the Input-Output frameworks used by researchers in the US, there is commonly a specific oil and gas drilling services sector described within the tables, showing the purchasing and sales linkages of the sector. This is absent in the framework for Wales. Additionally, US tight production is characterised by the convergence at well-heads of multiple companies with experience in onshore oil and gas combining knowledge and machinery to undertake extraction and distribution operations. Given the limited onshore oil and gas expertise, infrastructure and relevant tooling in Europe, the exact mode of operation (and hence the modelled production function) in Wales is uncertain.

The above notwithstanding, the Input-Output analysis is the most appropriate and regionally bespoke methodology available to assess the potential economic impacts of unconventional gas extraction in Wales.

Development scenarios

The research underlying this analysis was started in 2015 and this was the original base year for the scenarios developed. However, the limited progress in unconventional gas development in Wales in the period to end 2017 makes for some flexibility in the time periods underpinning our development scenarios, and here we focus on a notional period of development between 2015 and 2029, accepting that current activity at 2017 aligns closely to our first development scenario in what follows. There was (and is) some uncertainty over the developmental path surrounding unconventional gas. For this reason a range of scenarios were used to examine the economic impacts of different development paths within Wales. The scenarios developed were specific to Wales, but were made to be broadly consistent with the development activity which may occur elsewhere in the UK.

Information is limited on the technically recoverable resource in Wales. Therefore scenarios were constructed on the basis of different levels of investment activity and hence exploration and production occurring within Wales. There was a more extensive economic impact evidence base for shale gas than for CBM. Whilst there were gaps in the evidence, there was sufficient information to differentiate between the extraction of shale gas and CBM within the scenarios (although we examine the impacts of CBM and shale gas separately). The basis of the three scenarios is set out in Table 1. In summary:

- Low Scenario (3 CBM pads) – A focus on CBM development. Uncertainties and other barriers to widespread development remain. Global energy prices continue to provide limited incentives to invest in unconventional gas in the UK.
- Medium Scenario (4 CBM pads, 1 Shale Gas pad) – Step Up in Exploration and Production in Wales. A number of the barriers and aspects of uncertainty affecting the industry are lessened or removed. Global energy prices provide a greater incentive in developing extraction in the UK compared to the low scenario.

- High Scenario (12 CBM and 8 Shale Gas pads) – Significant Step Change. Uncertainty affecting the industry is greatly reduced stimulating significantly higher investment activity across the UK. Although not as rapid as in other parts of the UK, the increase in shale gas activity also occurs in Wales. This increase may also be stimulated by market factors such as a much higher increase in energy prices in the medium (eg 2-5 years) to long term (over 5 years). The likelihood of this scenario occurring is judged to be fairly low.

The proposed scenarios allow for a number of aspects of uncertainty (see below). Our analysis focuses on activity in a notional 15-year period 2015-2029 (inclusive), up to the decommissioning of this activity (shale and other unconventionals are at zero commercial scale in Wales and there would a be a considerable lead-in time before production, covering planning and funding activities but we accept this period is somewhat notional). Consequently all of the expenditure associated with the lifecycle of the additional activity is captured and expenditure could feasibly occur for some years after 2029. In terms of the expected duration of activity existing UK studies make varying assumptions for the duration of lifetime activity per well and the proportion of this accounted for by actual production activity (ranging between, at maximum, 15 and 20 years productive life). Emerging experience from the US is pointing to shorter well lives and so we err on the side of caution in assuming the following for a well: enabling activity in year one; site preparation in year two; drilling and testing in year three and possibly year four subject to the scale of activity; production over a subsequent decade to 15 years; decommissioning over a one year period.

With respect to the location-intensity of production activity, US evidence suggests a high intensity of activity per pad for shale gas (i.e. number of laterals drilled per pad) and this has been reflected in some UK studies (see Regeneris et al., 2015) with 40 laterals per pad being a common place assumption. In this study we employed a more conservative range to reflect the general uncertainty (between 10 and 24 laterals per shale pad).

Data sources

A range of data sources informed the assessment, including estimates of capital and operational spending expected to be associated with commercial shale gas and CBM extraction in Wales. To ensure consistency with other studies this required estimates of the expenditure associated with the different phases of activity. Decommissioning costs are also included, which will inflate economic impact estimates for unconventional gas compared to other developments (where decommissioning is often excluded). Relevant expenditures were then categorised according to the industry sectors described in the Welsh Input-Output Tables, with an assumption made in each case around how much of that expenditure is likely to occur in Wales as opposed to elsewhere, either under current or improved local supply conditions (see later below).

The data available to estimate the likely pattern of expenditures in the UK commercial shale and CBM exploitation are very limited, and necessarily *ex ante*. There is no robust data on the level of regional sourcing. A small number of US studies are based on actual commercial exploitation in the Marcellus shales and in the lower-48 states overall. These studies present useful estimates of spending according to specific and detailed industrial classification at exploration, drilling and operations stages, respectively. A significant caveat is that the actual cost of, and technical approach to, production of shale and CBM in Europe is unknown. Due to geological, infrastructure and other factors, it is unlikely to be identical to (or as favourable as) the USA. However, in the absence of Europe-specific data, US evidence on the different vectors of spend associated with exploitation was useful in the framing the regional sourcing analysis (see below).

To produce an estimate of the cost per well for the UK shale gas and CBM, the analysis amalgamates the US data on spend vectors with the UK estimates on costs (see for example, IHS, 2012). Given uncertainty over the evolution of shale exploitation, the assessment has used total costs for the lifetime of the well, presented in 2014 prices. In terms of exploration and extraction lifetime costs – there is uncertainty around the likely average costs of extraction for shale gas in the UK with an average of £9.3m per lateral taken here using as a guide figures in other reviewed UK studies (see for example Institute of Directors 2013; Ernst and Young, 2014). This estimate was used as the basis of lifetime costs with some allowance for economies of scale as production activity escalates at a UK and Welsh level. There is far less information available for the extraction costs of CBM although the available evidence points to it being typically lower. In the analysis it is assumed lifetime capital expenditure (capex) and operational expenditure (opex) costs of £700,000 per well in the CBM case.

This estimate of new economic activity is then used as an input to the Input-Output Tables for Wales to estimate the direct, indirect and induced levels of gross value added (GVA) and employment. Then these impacts are aggregated to produce the scenario estimates based on numbers of pads. Table 2 below provides an indication of the overall lifetime expenditure associated with each of the scenarios, allowing for a variation in the intensity of development on the pads under each of these scenarios.

It should be noted that this aspect of the assessment deals only with the positive economic impact associated with unconventional gas extraction. It makes no comment on the likelihood or viability of such investments given wider economic, energy cost, environmental and social contexts. Moreover, this analysis provides no consideration of wider and more negative economic effects associated with issues including property price changes around extraction sites, local labour market effects, effects on tourism demands, and costs associated with protest and infrastructure disruption around sites.

Table 2 about here

Regional sourcing assumptions

The opportunity for Wales to benefit from any expansion of unconventional gas will depend on factors such as: the speed with which the current industrial and service sector in Wales can re-align activity to match industry requirements; the potential for inward investment by new firms to occur in Wales to meet any shortfall in the supply chain, or the extent to which it is met by providers that continue to be located outside Wales (as suppliers in other parts of the UK, such as Scotland and the North East, will be seeking to supply the Welsh market).

In considering the opportunities for local sourcing we considered different phases of development and operation, and then how far there was an existing ability to supply relevant products and services regionally (this was based on information from the Jordans-FAME database and the Office for National Statistics, *Business Register and Employment Survey*) and then the extent to which there was potential for the supply chain to develop through time. Then there was a need to consider how different developmental scenarios might imply different local sourcing scenarios (as regional capacity constraints relaxed as the scale of activity increased and with incentives for firm start-up and relocation), and to consider where costs fell due to scale economies. Moreover, care is needed because the current structure of the supply side of the economy in Wales could change were the industry to grow such that new firms could come in to serve this industry, or new indigenous firms could set up. There are therefore a series of unknown factors.

However, the evolution of the unconventional gas sector in other parts of the UK and Europe is expected to have a marked effect on the extent to which future development in Wales will be able to take advantage of a local supply side. For example, if developers access commercially significant shale gas deposits in other parts of the UK prior to Wales (and with some activity underway in Lancashire, Cheshire and parts of Yorkshire), then suppliers in other regions may gain a strong element of first mover advantage. A corollary here is the challenge for existing Welsh firms with appropriate expertise to win opportunities in expected shale gas development projects in other parts of the UK, therefore putting them in a better position to win business once, and if, development occurs in Wales.

The approach adopted here was to identify the commodities employed in both developing and operating shale gas and CBM, and how developers typically distributed expenditure. Reference was also made to the typical distribution of development and operational spending in US studies (see for example, IHS, 2012). Table 3 shows an estimate of how typical development and operational spending on unconventional gas development (combining both shale and CBM) is expected to be distributed across UK defined industries. Note here that this includes industry activity in terms of drilling capital spending, completions, facilities and gathering capital spending, as well as on-going operational expenditure.

Table 3 shows that around one quarter of total spending relates to the defined "Support activities for petroleum and natural gas extraction" and with around 18% estimated to be spent in the "Manufacture of metal structures and parts of structures". Around 8% would be spending on the products of the "Operation of gravel and sand pits etc." sector. A problem here is that in the level of disaggregation (five digit Standard Industrial Classification 2007) there could be fairly diverse activities. For example, while around 4% of spending is on "Manufacture of fluid power equipment and pumps" this embraces many different types of equipment some of which would not be suitable for use in the unconventional gas industry. This is important in context of local sourcing assumptions. For example, while Wales has strong representation in a sector such as "Manufacture of metal structures etc." it is not clear whether this industry in Wales would be able to produce the specific requirements of the unconventional gas industry or indeed whether it would be willing to serve a small evolving sector. The following columns of Table 3 provide an outline of how far the sectors which could serve the unconventional gas sector are actually present in Wales. The second column reveals employment in Wales in sectors that could serve unconventional gas, and with regional specialisation in these sectors (measured by a simple location quotient (LQ in the third column) which is an industry's share of a regional total employment divided by the industry's share of the national total of employment). A further check is through an analysis of the number of registered offices where local firms list the five digit Standard Industrial Classification as their main activity (fourth column). This was derived from the Jordan FAME (Information submitted to Companies House) database. This takes no account of the size of operation but hints at the depth of the regional supply side in these industries.

Examination of the material in Table 3 revealed the current weaknesses in the supply chain in Wales when compared to the likely supply chain profile for unconventional gas development. For example it was estimated that “Support activities for petroleum and natural gas” could account for around one quarter of total developmental and operational expenditure, while Table 3 reveals relatively little activity in Wales. On this basis there was better evidence for supply chain links in sectors such as “Operation of gravel pits” and “Manufacture of metal structures”, where these sectors account for a larger part of total development and operational spending and where there is relatively strong representation in the Welsh economy.

The final columns of Table 3 present the local sourcing assumptions that would link with the Low and Medium (Step-up) and then High scenarios (see earlier). Generally the expectation is of higher levels of Welsh sourcing of goods and services where there is a higher local presence in the industry, and with selected sectors producing commodities that are expensive to transport such as cement and mined/quarried products. We expect far lower levels of local sourcing in some specific manufacturing sectors and in the “Support services for petroleum and natural gas extraction” where there is relatively little employment presence currently.

In the Medium scenario, the same local sourcing assumptions are used as for the Low scenario but we adjust the spending to include local community benefit payments (with shale gas developers expected to make provision for communities deemed to be affected by new development – see HM Treasury, 2016). This is in a range £1.86m to £4.33m (i.e. around 2% of total expenditure) due to the inclusion of shale gas in the production mix. This process with respect to community benefits is replicated for the high scenario, but with a greater spending reflecting the higher scale of activity.

The high scenario (Significant Step Change) sees a major uplift in shale gas production activity and a range of total expenditure on lateral well drill and production of £772.0m (High Scenario –

Lower Intensity) to £1,815.0m (High Scenario – Higher Intensity). It is expected that this level of activity would lead to some new inward investment into Wales to supply the sector and with it the development in the indigenous supply side as a result, and firms in relevant Welsh sectors diversifying and expanding to meet the demand, particularly in cases where there is already regional employment representation and where there is greater scope for diversification to meet growing demand.

Table 3 about here

The final column of Table 3 shows the higher local sourcing proportions that are used to inform the economic modelling of the High Scenario. In particular we expect local sourcing to grow in "Support activities for petroleum and natural gas extraction" from 5% to around 15%. With an increase in activity, businesses in this sector tend to be fairly mobile and able to respond to new opportunities in different places. We also expect some expansion of local sourcing with higher levels of industry activity in Professional services for much the same reason, although here this would be from an existing base of activity and could reflect diversification of existing firms in the sector in Wales to serve the unconventional gas sector.

The local sourcing assumptions have also been adjusted upwards for selected manufacturing where we believe there is scope for expansion from a relatively low base of activity including manufacture of fluid power equipment and pumps, manufacture of tubes and pipes, manufacture of tanks, and manufacture of electrical instruments. It is accepted that these local sourcing scenarios reflect an element of judgement in terms of the proportions that could be purchased from local firms. Table 4 summarises the regional spending expected under the different scenarios i.e. allowing for expected spending leakages outside of the region.

Table 4 about here

Results

The economic modelling uses the estimates of capital and operational spending for the combined scenarios of CBM and shale gas explained above.

For the purposes of examining economic effects in Wales the costs associated with the Low, Medium and High scenarios are examined as a block of spending over the period 2015-29 to provide an insight into the amount of economic activity in Wales that could be supported by developments. In common with other novel energy investments (and indeed to a perhaps greater degree) the timescale of investment and hence economic impact is uncertain.

Whilst the assessment assumes a 15-year aggregate and average annual employment and GVA impacts over this period, it is towards the end of this period that the investment will likely occur. Due to uncertainties over timing of investments and consequent impacts, the assessment has not discounted the economic impacts to return a net present value (mirroring other energy impact studies undertaken in Wales – see Bryan et al., 2017). It should be remembered that economic impact arising further in the future (and hence generally more uncertain) may be considered of lower value than more timely, concrete investments.

The results from the regional economic modelling for the low, medium and high scenarios are found in Tables 5-7. Each table has two panels. The uppermost provides the estimate of total economic impact occurring over the whole period under the lower and higher intensity development and operational spending ranges of the three separate scenarios. These estimates combine direct, indirect and induced economic effects (i.e. activity supported as the industries involved purchases goods and services in Wales themselves, and associated effects linked to the spending of wage income). Economic activity is measured in terms of Welsh output, gross value added, and employment. Employment is measured in terms of person years of employment for the total period. The bottom panel of each table shows the average annual economic impact over the period 2015-2019 and here employment is in terms of full time equivalents (FTEs). Each table also reveals in broad terms where the economic effects will occur in the regional economy by sector.

Table 5 about here

Table 5 shows the results associated with the Business as Usual Low scenario and with this the associated estimate of total expenditure in the range of £9.21m to £13.05m for lower and higher intensity development. This reveals that these levels of activity would support between £4.4m and £6.5m of total output, and £1.7m to £2.4m of GVA in Wales. This output and GVA would equate to between 39 and 56 person years of employment supported in total. Were these effects converted into a simple average annual effect over the period this would equate to £0.3m to £0.4m of output, and £0.1m to £0.2m of GVA per annum. In employment terms this would range from 2.6FTEs to 3.7FTEs. Much of this economic activity would be supported in the manufacturing, energy and construction sector (i.e. over 50% of output effects and 40% of the employment effects), with much of the remaining activity focused in the private services sector.

Table 6 shows the results associated with the Medium scenario, with estimated expenditure ranging from £106.8m to £235.0m for the lower and higher intensity development assumptions. This shows that these levels of activity would support between £55.6m and £122.1m of total output, and £21.1m to £46.6m of GVA. This output and GVA would equate to between 510 and 1,080 person years of employment supported in total. Converting these estimated effects into a simple average annual effect over the period 2015-29, would equate to £3.7m to £8.1m of output, and £1.4m to £3.1m of GVA per annum. In employment terms this would range from 34FTEs to 72FTEs. Again much of the economic activity (an estimated 48% of output) under the Medium scenario would be supported in the Manufacturing, Energy and Construction sector, and 38% of the employment.

Table 6-7 about here

Finally Table 7 shows the results associated with the High scenario, and with this associated with a lower intensity spend estimate of £772.0m and a higher intensity estimate of £1,815.0m. This reveals that these levels of activity would support between £442.2m and £1,040.0m of total output, and £170.4m to £400.4m of GVA. This output and GVA would equate to between 4,010 and 9,410 person years of employment supported in total. Converting these estimates into a simple average annual effect over the period 2015-29, this would equate to £29.5m to £69.3m of output, and £11.4m to £26.7m of GVA per annum. In employment terms this would range from 267FTEs to 627FTEs. Around 36% of the employment effects would be in the Manufacturing, Energy and Construction sector and with 28% of the employment effects within Other Private Services.

Looking across the scenarios, the distribution of GVA effects varies between the Low and then the Medium/High activity scenarios. For example: under the Low Activity High Intensity scenario an estimated 47% of GVA effects would be in the manufacturing, energy and construction sector, and an estimated 37% of GVA effects in private services.

In contrast, under the Medium/High activity scenarios the GVA effects in the Manufacturing sectors fall to 38% in both cases, whereas the GVA effects in Private services fall to 35% under the Medium Activity High Intensity scenario to just 31% under the High Activity High Intensity scenario. Therefore higher levels of expected activity would see a higher proportion of total GVA effects in other sectors as the supply side of the Welsh economy adapted to take advantage of the opportunities

Conclusions and discussion

The analysis was focused around notional scenarios and with, as yet, very limited evidence on the cost structure of shale gas and CBM operations in the UK. Moreover, there is still little clarity on the expected revenues that will be available from the developed resource (either locally arising or in total from customers). Notwithstanding the analysis of the scenarios here has provided something of a reality check on the expected effects of developments at the regional level.

Inevitably effects in Wales will be constrained by the availability of the shale gas resource. Perhaps as importantly will be the 'ordering' of any developments in the UK around unconventional gas. Then economies in the periphery might lose out to the presence of UK/foreign international capital that serves the sector from areas adjacent to where the first rounds of extraction occur. For example, were developments to take place in England prior to Wales, then firms serving English projects may gain important elements of first mover advantage and be in a strong position to serve Welsh projects in the future. Indeed at the time of writing in Autumn 2018, developments are far more advanced in England, for example at the Cuadrilla sites in Lancashire and the Third Energy site in Yorkshire, as shown earlier in the paper. Then developers with PEDLs in Cheshire and Yorkshire would be expected to begin production of shale gas well before any developments occur in Wales, and with this conclusion reinforced by the declared position of Welsh Ministers on the issue of hydraulic fracturing. Clearly some businesses in North east Wales could stand to benefit from any shale gas development in Cheshire. Notwithstanding this, the absence of a supply side in the regional (and indeed national) economy works to severely constrain the regional economic effects even from the Medium and High scenarios developed in this paper. Were unconventional gas to become a more prominent part of regional activity then regional policymakers would need to carefully audit how far local manufacturers are in a position to diversify into servicing the industry needs. At the same time policymakers need to understand that unconventional gas economic impacts reported here are likely to be transitory with much of the regional economic activity supported during early stage operations, and with drilling crews expected to be highly mobile. Indeed for the Welsh economy elements of unconventional gas development would actually share some of the characteristics of general energy infrastructure construction (see for example Bryan et al., 2017). Then activity around shale gas and CBM is unlikely to be an activity that is well embedded in the local economy, and with this conclusion more evident in cases where developments are undertaken by out of region firms, which have established supply chains elsewhere.

Another issue to consider is whether gas produced in the region is actually used in the region. While there might be some prospect of gas being used in local energy generation (see Sarhosis et al., 2016) there is still uncertainty over the scope of regional industries such as chemical processing to readily use locally produced gas, and moreover it is unlikely that any future Welsh production would materially affect commercial gas prices in the region.

Then the conclusion here would be that unconventional gas in Wales is unlikely to be of the scale and nature to create any longer term transformative economic effects for the region. What might be relevant in terms of addressing socio-economic needs around drilling sites is the scale of community benefit provisions expected around shale drilling sites, and with these types of community benefit provisions known to have important local effects in the case of other energy related investments in the region (see Munday et al., 2011).

Finally, in terms of assessments of economic prospects linked to unconventional gas in other regions of the UK we would argue that future analysis needs to carefully factor in the strengths of both the regional and national supply side to serve such investments, and carefully consider the time trend in economic effects, and the dispersion of economic opportunities as projects develop.

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Figure 1 Outline of Economic Modelling Framework

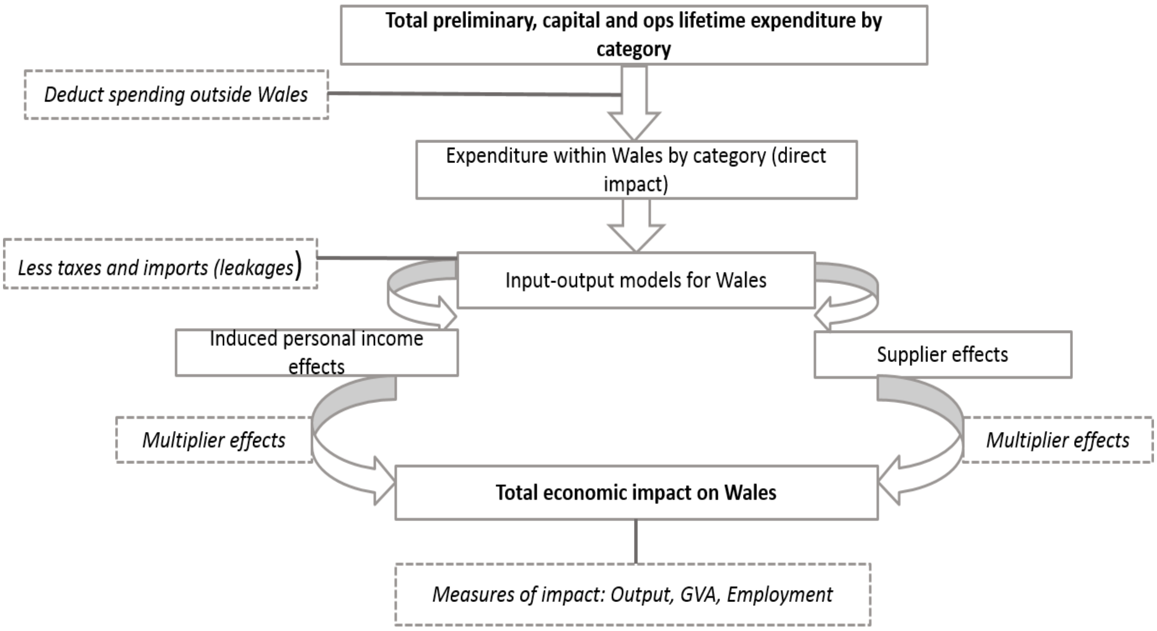

Table 1: Unconventional gas in Wales: Development Scenarios Summary

<table>
<tr><th>Scenarios</th><th>Fuel Type</th><th>Exploration (bores drilled)</th><th>Pads</th><th>Production Intensity (CBM Wells or Laterals/ Pad)</th><th>Total</th></tr>
<tr><td rowspan="2">Low. Uncertainties and other barriers to development. Energy prices continue to increase steadily. Consequently, on-going but limited exploration continues, leading to some small scale production later in the period.

Exploration is initially focused on CBM and SG later in the period. Production activity is restricted to CBM in the period.</td><td>CBM</td><td>25.5</td><td>3</td><td>Low 4 to High 6</td><td>Low 12 to High 18</td></tr>
<tr><td colspan="2">Assumes 17 existing licences and similar number through 14th licensing round. Average 0.75 bore holes per licence</td><td>Three CBM pads with production first coming on stream early 2020</td><td colspan="2">Use of range allows for different potential intensity of drilling and well activity given the uncertainty about the resource.</td></tr>
<tr><td rowspan="3">MEDIUM A number of the barriers and aspects of uncertainty affecting the industry are lessened or removed and possibly a higher increase in energy prices than under the low scenario.

A number of pads are developed in South East and North East Wales, with CBM development occurring sooner in the period, given the greater knowledge of the resource. Shale gas production comes on stream later in the period (2025), given the greater time needed to establish the nature of the resource.</td><td>CBM</td><td>61</td><td>4</td><td>Low 4 to High 6</td><td>Low 16 to High 24</td></tr>
<tr><td>Shale Gas</td><td>41</td><td>1</td><td>Low 10 to High 24</td><td>Low 10 to High 24</td></tr>
<tr><td colspan="2">Assumes 17 existing licences and similar number through 14th Round. Average 3 bore holes per licence</td><td>Four CBM pads with production coming on stream 2020 onwards (split between NE and S Wales). A single SG pad comes on stream 2025.</td><td colspan="2"></td></tr>
<tr><td rowspan="3">HIGH Uncertainty affecting the industry is greatly reduced stimulating significantly higher investment activity across the UK. Although not as rapid as in other parts of the UK, the increase in SG activity also occurs in Wales. This increase may also be stimulated by other supply side considerations, such as a much higher increase in energy prices.

The assumed scale of development and production represents a higher share of UK high scenarios in order to test the potential supply chain impacts.</td><td>CBM</td><td>109</td><td>12</td><td>Low 4 to High 6</td><td>Low 48 to High 72</td></tr>
<tr><td>Shale Gas</td><td>231</td><td>8</td><td>Low 10 to High 24</td><td>Low 80 to High 192</td></tr>
<tr><td colspan="2">Assumes 17 existing licences and similar number through 14th Round. Average 10 bore holes per licence</td><td>Assumes 12 CBM pads and 8 SG pads. SG development and production occurs on a slightly delayed timescale compared to CBM.</td><td colspan="2"></td></tr>
</table>

Table 2: Estimate of Gross Capital and Operational expenditure for differing scenarios (based on average per well exploration, drill and production costs), £millions

	Low Intensity Drilling	High Intensity Drilling
Low Scenario - Business as Usual	£9.2	£13.1
Medium Scenario - Step up in Exploration and Production	£106.8	£235.0
High Scenario - Significant Step Change	£757.1	£1,780.4

Notes: the difference in low and intensity drilling is driven by the assumption concerning the number of wells drilled per pad. That is, between 10 and 24 laterals per pad for shale gas and 4 to 6 wells per pad for CBM.

Table 3 Wales Sourcing Assumptions for the Low, Medium and High Development Scenarios

Description of Activity	Est. Dist. Dev & Operational spending (%)	Employ in Wales (2013)	LQ Wales	No. Registered Offices	Local sourcing Scenario: Low/Med	Local Sourcing Scenario: High
Support activities for petroleum and natural gas extraction	24.6	<200	0.12	25	5%	15%
Operation of gravel and sand pits	8.2	440	1.41	7	75%	75%
Manufacture of cement	0.3	240	2.65	3	75%	75%
Manufacture metal structures etc	18.3	3,580	1.62	184	75%	75%
Manufacture of tools	7.2	370	0.56	15	15%	15%
Manufacture of mining machinery	9.9	<100	0.12	4	0%	0%
Manufacture fluid power eqmt.	4.3	380	0.47	6	0%	15%
Manufacture of compressors	6.2	<100	0.03	0	0%	0%
Manufacture of tubes, pipes etc	2.1	380	1.10	9	15%	30%
Sewerage inc waste water	4.1	906	0.85	35	100%	100%
Manufacture other inorganic chem.	4.1	<200	0.94	17	15%	15%
Manufacture of industrial gas	4.1	90	0.79	0	50%	80%
Freight transport by road	0.6	8,100	0.97	627	80%	80%
Manufacture tanks and containers	1.5	290	1.38	6	15%	30%
Manufacture of elec.components	0.6	1,840	2.47	40	50%	50%
Manufacture of electrical inst.	0.2	1,060	0.51	21	15%	30%
Manufacture engines and turbines	0.1	770	1.04	4	0%	0%
Manufacture of steam generators	0.1	150	1.64	0	0%	0%
Professional services	3.4	2,840	0.89	245	50%	75%
	100.0	21,440		1248		

Note: Planning, design and legal services associated with project development were modelled in the analysis that follows as part of professional services as this links to the sector descriptor in the Welsh Input-Output tables.

Table 4 Sector Spending In Wales by Scenario and Intensity of Activity £000s

	Low Scenario		**Medium Scenario**		**High Scenario**	
	Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity	Lower Intensity	Higher Intensity
Total CAPEX and OPEX	9,210.0	13,050.0	106,811.4	235,000.1	757,141.5	1,780,352.4
Total Regional Spend	2,964.6	4,200.6	34,381.3	75,643.7	287,287.1	675,530.7
Spend in Wales as % Total	32%	32%	32%	32%	38%	38%

Note: Total spend in Wales excludes community payments and land purchase or access payments

Table 5 Total and Annual Economic and Employment Impacts – Low Scenario

	Low Scenario – Lower Intensity			**Lower Scenario – Higher Intensity**		
Total Scenario Expenditure Expenditure in Wales	£9.21m £2.95m (32%)			£13.05m £4.18m (32%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	0.7	0.2	3	1.0	0.3	5
Manufacturing, Energy & construction	2.3	0.7	16	3.3	1.0	23
Distribution & Transport	0.3	0.2	6	0.5	0.2	8
Other Private Services	1.1	0.6	13	1.6	0.9	19
Public Sector	0.0	0.0	1	0.1	0.0	1
TOTAL	4.4	1.7	39	6.5	2.4	56
Average pa economic impact 2015-2029	0.3	0.1	2.6 (FTE)	0.4	0.2	3.7 (FTE)

Table 6 Total and Annual Economic and Employment Impacts – Medium Scenario

	Medium Scenario – Lo Intensity			**Medium Scenario – High Intensity**		
Total Scenario Expenditure	£106.8m			£235.0m		
Retained Expenditure in Wales	£34.1m (32%)			£75.5m (32%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	8.2	2.3	40	18.0	5.1	80
Manufacturing, Energy & construction	26.8	8.0	190	58.9	17.6	410
Distribution & Transport	3.8	1.8	70	8.3	4.0	150
Other Private Services	13.1	7.3	160	28.7	16.2	340
Public Sector	3.7	1.7	50	8.2	3.7	100
TOTAL	55.6	21.1	510	122.1	46.6	1,080
Average pa Economic Impact 2015-2029	3.7	1.4	34.0 (FTE)	8.1	3.1	72.0 (FTE)

Table 7 Total and Annual Economic and Employment Impacts – High Scenario

	High Scenario – Lower Intensity			**High Scenario – Higher Intensity**		
Total Scenario Expenditure	£757.1m			£1,780.4m		
Retained Expenditure in Wales	£287.3m (38%)			£675.5m (38%)		
Total Economic Impact 2015-2029	Output (£m)	GVA (£m)	Emp Person Yrs	Output (£m)	GVA (£m)	Emp Person Yrs
Mining, Quarrying & Minerals	79.0	25.0	530	185.9	58.7	1,240
Manufacturing, Energy & construction	219.6	65.3	1,480	516.4	153.5	3,480
Distribution & Transport	29.7	14.3	530	69.9	33.6	1250
Other Private Services	93.9	53.5	1,130	220.8	125.7	2,650
Public Sector	20.0	12.3	340	47	28.9	790
TOTAL	442.2	170.4	4,010	1040	400.4	9,410
Average Annual Economic Impact 2015-2029	29.5	11.4	267.3 (FTE)	69.3	26.7	627.3 (FTE)