Experience Curve for Natural Gas Production by Hydraulic Facturing

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OVERVIEW

Hydraulic fracturing technology, or "fracking", spurred the massive increase of shale gas production in the U.S. over the past 10 years. Beginning around 2005, the shale gas revolution has helped the U.S. reach unprecedented levels of natural gas production. Unsurprisingly, the increase of unconventional gas production impacted the U.S. natural gas market, causing a sharp decline in the wellhead price (Mazur, 2012). As hydraulic fracturing techniques and drilling technology continue to develop, resulting in additional production increases, further price declines are possible. Both the private and public sectors value analysis regarding the potential effects on market prices of continued growth in unconventional gas production. In this article, based on an inspection of progress achieved in the field of hydraulic fracturing technology so far, we provide an indicator for potential future gas price reductions.

While plenty of literature exists on price and manufacturing cost reductions, as well as on learning-by-doing phenomena, for a large range of energy technologies, comprehensive research on price reductions for the use of hydraulic fracturing technology has not yet been undertaken. As production of unconventional natural gas continues to grow, it is insightful to investigate past and prospective gas price developments. This article presents an experience curve for the US natural gas industry from the start of the shale gas revolution. We examine the impact of increased shale gas production on the wellhead price of natural gas, and show that a learning-by-doing trend exists that reflects past achievements deriving from the accumulation of experience. This trend may be indicative for future price developments, or even for the prospects of the gas industry as a whole. We present an experience curve that may provide insight into one of the factors determining future gas price levels and that, complemented with other price development indicators as well as ancillary knowledge on limitations to its extrapolation, could possibly be used as empirical information for strategic considerations in industry, as background material for public policy planning, or as input for climate change mitigation research. For instance, in principle this experience curve could be implemented in integrated assessment models as used for low-carbon energy technology diffusion studies such as by the Intergovernmental Panel on Climate Change (IPCC, 2014), although such models normally require cost-data rather than price-based information as input.

METHOD

$$P(x) = P(x_0)\,(x/x_0)^{-L}$$

x:	*Cumulative output*
$P(x)$:	*Price at cumulative output*
L:	*Learning parameter*
$LR = 1 - 2^{-L}$:	*Learning rate*

Experience curve analysis is a method for expressing the relationship between price reductions and cumulative production of a good or technology. The experience curve is related to the learning curve, which is a way of illustrating the relationship between cost reductions and cumulative production (see Wene, 2000), for details on the distinction between these two concepts). Based on the correlation between price and production observed for the past, experience curves yield information for potential price reductions in the future. The steepness of the experience curve, expressed by the value of the learning rate, identifies the rapidity of structural market, manufacturing, or industry change for in principle any technology. The experience curve methodology stipulates that every doubling of cumulative production of a certain commodity or technology generates a constant relative reduction (in %) of its price, which is the learning rate.

RESULTS AND IMPLICATION

The experience curve depicted in Fig 2 captures the shale gas revolution from a perspective of industrial production and price data in the period 2005–2015. The learning rate of this curve is 13%, that is, a doubling of shale gas output results on average in a 13% fall in constant US(2009)$ terms of the price of natural gas. The R^2 of this regression is 0.66, hence the fit is reasonable but implies by no means a conclusive statistical reliability. In order to derive a statistically more significant experience curve, future analysis should incorporate a larger data set, ideally covering at least two orders of magnitude of expansion of cumulative production of shale gas, as pointed out in Ferioli et al. (2009). The 13% steepness of our learning curve is an indicator for the speed of experience gained by the industry from new hydraulic fracturing technologies and drilling techniques.

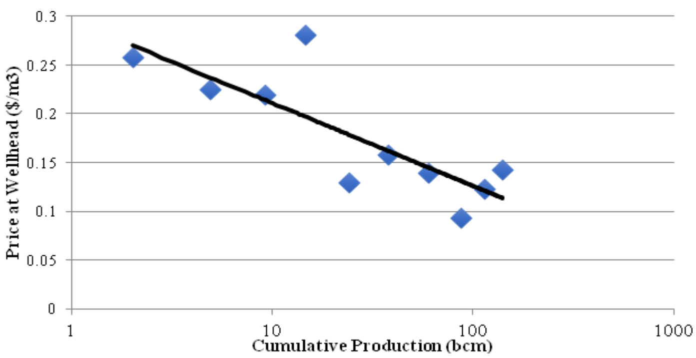

Fig 2: Experience Curve for Natural Gas Production by Hydraulic Fracturing. (Data from 2005 to 2015).

There are a number of factors that can limit the further production of unconventional gas. Correspondingly, there are factors affecting the stability of the experience curve, both internal (or endogenous) and external (or exogenous) to the learning system. The distinction between these two types of factors is policy relevant, because internal disturbances may threaten the survival of the learning system, while the learning system may have mechanisms to handle external disturbances (see, e.g., Wene, 2015).

CONCLUSION

From 2007 to 2012 shale gas production in the U.S. expanded at an astounding average growth rate of over 50%/yr, and thereby increased nearly tenfold over this short time period alone. Hydraulic fracturing technology, as well as new directional drilling techniques, played key roles in this shale gas revolution, by allowing for extraction of natural gas from previously unviable shale resources. Although hydraulic fracturing technology had been around for decades, it only recently became commercially attractive for large-scale implementation. As the production of shale gas rapidly increased in the U.S. over the past decade, the wellhead price of natural gas dropped substantially. In this paper we express the relationship between wellhead price and cumulative natural gas output in terms of an experience curve, and obtain a learning rate of 13% for the industry using hydraulic fracturing technology. This learning rate represents a measure for the know-how and skills accumulated thus far by the U.S. shale gas industry. The use of experience curves for renewable energy options such as solar and wind power has allowed analysts, practitioners, and policy makers to assess potential price reductions, and underlying cost decreases, for these technologies in the future. The reasons for price reductions of hydraulic fracturing are fundamentally different from those behind renewable energy technologies – hence they cannot be directly compared – and hydraulic fracturing may soon reach, or maybe has already attained, a lower bound for further price reductions, for instance as a result of its water requirements or environmental footprint. Yet, understanding learning-by-doing phenomena as expressed by an industry-wide experience curve for shale gas production can be useful for strategic planning in the gas sector, as well as assist environmental policy design, and serve more broadly as input for projections of energy system developments.

While this experience curve may help illustrating the "learning-by-doing" effect for hydraulic fracturing in the U.S., it must be handled appropriately in order to offer robust and reliable considerations for energy policy making and strategic purposes. In particular due attention needs to be given to the fact that experience curves eventually level off. The important question that still needs to be answered is when and at what total cumulative capacity this leveling off will occur for hydraulic fracturing (see Ferioli et al., 2009). Also, experience curves themselves offer little explanation with regards to the underlying technological change, reasons for learning, and causality between cumulative output and price reductions of production (Yeh and Rubin, 2012). In our case, much still needs to be understood with regard to why precisely learning occurred in the U.S. shale gas industry: was it due to an increased number of wells drilled, or maybe the number of wells completed per square kilometer, or perhaps the number of fracture stages, or possibly higher production volumes per well drilled? These are the sorts of questions that further research could potentially answer. In order to better place our experience curve and corresponding price-production relationship into perspective, we have discussed some of the main factors that may affect the experience curve for hydraulic fracturing into the future.

As the U.S. transitions to the world's top natural gas producer, there are a number of factors to consider that may advance or hinder further unconventional gas production. Tighter regulations for the use of chemicals and water may on the one hand obstruct further gas price declines, while on the other hand encouraging further technological development of hydraulic fracturing as producers are forced to become more efficient in the production process. At the same time, stricter policy measures to regulate where and how a well may be hydraulically fractured can potentially result in reduced production. Such exogenous factors can affect the shape and slope of the hydraulic fracturing experience curve. Continued increases in output will eventually lead to a point at which the wellhead price of natural gas no longer falls. Such a price floor, hotly debated by specialists in the industry, implies a flattening of the experience curve. Further research is needed to assess the potential effects of low gas prices. Too low a spot price may limit unconventional production, while too low a wholesale price may create an oversupply problem. More analysis is also required on R&D investment trends and on the application of hydraulic fracturing technology outside the U.S. and in other (energy) sectors.

Footnote

To see the full paper, see the publication in Energy Policy: http://www.sciencedirect.com/science/article/pii/S0301421517301027

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SANDS HOTEL INTERVIEW (continued from page 20)

day, we work closely with business events professionals from around the world to co-create memorable experiences for their communities. We could be planning an event two years down the road, having endless discussions over Skype to tweak plans and make them perfect. The magical moment comes when our clients thank us for a job well done – to me, making a difference in the process of creating a successful event, is one of the most inspiring aspects of my job.

7. Last but not least do you have any interesting facts about the hotel and the past events which were organized at MBS which will be interesting for our readers?

Few would have thought that a hotel and an exhibition venue would be able to host para-Olympians and the demanding nature of their sports competitions. But we did it in December 2015. The ASEAN Para Games was special as the various divisions in Marina Bay Sands worked closely with the APG Organizing Committee to conceptualize and create a "Games Village" within Marina Bay Sands where the special athletes lived, ate and interacted with their fellow counterparts from different countries.

We also leveraged on Marina Bay Sands' CSR platform "Sands for Singapore" as a platform, working with the organizer to amplify key objectives of the Para Games and truly celebrate the extraordinary. This included a special appearance by David Beckham at the Games Village to inspire the athletes. It was a magical moment that capped a successful event.