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Explaining experience curves for new energy technologies: A case study of liquefied natural gas

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A B S T R A C T

Many new energy technologies seem to experience a fall in unit price as they mature. In this paper we study the unit price of liquefying natural gas in order to make it transportable by ship to gas power installations all over the world. Our point of departure is the experience curve approach, however unlike many other studies of new energy technologies, we also seek to account for autonomous technological change, scale effects and the effects of upstream competition among technology suppliers. To our surprise we find that upstream competition is by far the most important factor contributing to the fall in unit price. With respect to the natural gas business, this may have implications for the future development in prices as the effect of increased upstream competition is temporary and likely to weaken a lot sooner than effects from learning and technological change. Another more general policy implication, is that while promoting new energy technologies, governments must not forget to pay attention to competition policy.

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1. Introduction

Natural gas is projected to greatly increase its share of total energy supply in the years to come, partly due to the success of combined cycle gas turbine electricity generation (CCGT), see e.g. EIA (2003). However, since a large part of discovered gasfields are situated too far away from the major gas markets to make direct pipeline transportation economical, liquefying the gas and transporting it by ship to customers is in many cases the only viable option. As a consequence liquefied natural gas (LNG) is regarded as one of the

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most promising sub-sectors of the energy industry. For instance, the U.S. is expected to increase its future LNG imports by more than sixfold in the next 20 years (EIA, 2003). Moreover, the introduction of LNG into new markets, such as China and India, may push the growth in the LNG sector even further, see Petroleum Economist (2005).

Numerous articles over the years have discussed the economics of LNG projects, particularly the price of a LNG liquefaction plant, see e.g. DiNapoli (1975, 1984) and DiNapoli and Yost (1991). And since the late nineties commentators have become more and more optimistic as plant prices appear to have decreased, see for instance Cornot-Gandolphe (2005). However, to our knowledge, there exists no econometric study in the economics literature of LNG supply chain input prices.

In this paper, we focus on the price of a LNG liquefaction plant, which is by far the largest cost component in the LNG value chain. Further, we address the following two research questions: What are the factors driving the apparent fall in plant prices? To what extent is the price of liquefaction likely to fall further? Although we concentrate on the special case of natural gas liquefaction, we think that the insights obtained in our study are as relevant for other emerging technologies in the energy industry. One example that we have in mind, is carbon capture and sequestration, which also involves on site construction of facilities treating vast amounts of gas, and as for LNG, are likely to be dominated by a few large engineering firms.

In order to answer the research questions we use historical data to estimate experience curves for liquefaction plant prices. The hypothesis is that liquefaction plant prices fall as the cumulative number of LNG plants increases due to increased experience with the construction process. In addition we also seek to account for autonomous technological change, scale effects and the effects of upstream competition among liquefaction technology suppliers. To our surprise we find that fluctuations in the number of upstream liquefaction technology suppliers explain most of the fall in prices. In fact, we are not able to identify any experience effect at all. This may have implications for the future development in prices as the effect of increased upstream competition is temporary and likely to weaken a lot sooner than effects from learning and technological change.

Experience curves may be powerful tools when it comes to explaining past and indicating future cost gains for relatively new technologies. In its basic form, an experience curve explores the relationship between accumulated production at time t and average cost of production at time t. It has been shown in numerous studies that a significant, negative trend can be found between the cost of a new technology and accumulated supply of this technology, take for instance electricity generation from windmills (IEA, 2000).

There are at least four, more fundamental, mechanisms at work behind an experience curve, see IEA (2000) and Clarke et al. (2006). First, as personnel engaged in the planning and production of the new product gain experience with the new technology, say an LNG liquefaction plant, they are likely to become more efficient and better organized. This process is often coined “learning by doing”, and was first formally described in the seminal paper by Arrow (1962). One of the earlier studies of “learning by doing” is Zimmerman (1982) who investigated the role of learning for the construction costs of nuclear power plants in the US. Zimmerman distinguished between learning that reduced construction costs and learning that improved the *ex ante* cost estimates, and found a significant learning effect for both.

Second, experience may also induce research and development (R&D) within the firm supplying the technology in question, which may lead to further cost reductions—so called process innovations. Some studies have tried to separate the effects of organizational learning and induced R&D by keeping track of targeted public funding to R&D projects, see for example Ibenholt (2002) and Jespersen (2002), while we treat them together as an experience effect.

Third, it is often the case that the market for a new technology is poorly developed, which limits the exploration of potential scale advantages in the production technology. As time goes by, the size of the market increases, and so does the scale of the average production unit. Thus, we will observe that costs decrease with accumulated production, but then it would be wrong to interpret this as an experience effect. This is pointed out in Hall and Howell (1985), and investigated in Isoard and Soria (2001). Moreover, in another early study of experience curves, Joskow and Rose (1985) looked at the development in construction costs of coal-burning generation units in the US, and found a learning effect which could be separated from the scale effect.

Fourth, technological progress may also be independent of experience with the product under study. For instance, it is argued that increased gas turbine efficiency combined with larger turbine units have reduced

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