Natural Gas: Depletion Risks and Supply Security Modelling [(⋆)]

Gas metano: rischi di esaurimento e modellazione della sicurezza delle forniture

Renato Guseo[1], Mariangela Guidolin[2]

[1] Dipartimento di Scienze Statistiche, Università di Padova
e-mail: renato.guseo@unipd.it

[2] Dipartimento di Scienze Economiche, Università di Padova

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1. Ultimate recoverable resource estimation: an overview

The natural gas abundance assessment at global and regional level is relevant because this is a *non–renewable* resource: its formation takes possibly millions of years. Measuring natural gas in the ground is a very difficult purpose because technical, economic, strategic and social viewpoints are partially conflicting or at least not independent from each other.

A great deal of inference and estimation is involved and new technologies are becoming increasingly efficient and reliable. See, for instance, recent advances in producing and measuring techniques (Vxmeter and Q-technology by Schlumberger) in Gould (2007). A confirmation of the existence of the conflicting interests and of corresponding "technical definitions" on diverse typologies in natural gas resources may be recognized in the different classifications systems adopted by Energy Information Administration (EIA), International Energy Agency (IEA), Oil and Gas Journal (OGJ), World Oil magazine (WOm), BP Statistical Review of World Energy (BPSR), World Oil and Gas Review (WOeni).

The main focus of the paper is dealing with the problem of natural gas reserves estimation through the characterization of the *evolutive production pattern* and *Ultimate Recoverable Resource* (URR) determination. The URR for natural gas is the "total amount of a finite resource which may be obtained at the end of extraction or production process as a result of all concurring forces" which provides an indirect and realistic account of reserves, once discounted with technological, economic and strategic conditions. Historical *production data* summarize the variable joint contributions of technological, economic and social effects, including dynamic learning, on a production of a finite resource. Extraction data may be interpreted within a *diffusion of innovation* framework under possible exogenous interventions. As a matter of fact, natural gas aggregate demand is strongly correlated with the diffusion of the corresponding technologies in transport, heating appliances, electric power generation, chemical reforming, etc.. The unknown asymptotic *market potential*, expressing the diffusion ceiling or carrying capacity in a quantitative marketing context under a *finite life cycle* hypothesis, plays the role of the unknown URR in the case of natural gas.

An analogous approach, generalizing the Hubbert's one, was expressed in Guseo and Dalla Valle (2005) and in Guseo *et al.* (2007) with reference to crude oil production. The

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generalized Bass model (GBM), see Bass *et al.* (1994), is the main tool and is combined with an ARMAX framework for the implementation of residual autocorrelated deviations not recoverable with the direct control of an intervention function that incorporates known and interpretable historical shocks of different origins.

The statistical and forecasting literature on URR estimation is quite limited with some important exceptions. Two reviews in this area are those by Adelman and Jacoby (1979) and by Kaufmann (1988). Recent econometric extensions of Hubbert model are provided by Kaufmann (1991), Cleveland and Kaufmann (1991) and Pesaran and Samiei (1995). These extensions are directly based on the logistic Hubbert model for cumulative or rate production data. There is no attempt to discuss the basic foundations/assumptions of Hubbert's model. New advances in Hubbert like modelling are provided by Berg and Korte (2006). They consider equations systems that jointly account for supply–demand and reserves dynamics performing a qualitative differential equation characterization.

The extended paper is organized as follows. In Section 2 we summarize the GBM framework with the motivations that justify our choice. The aim is to evaluate, with comparative scenarios, the relationships among *peak times* and *duration* estimates. In Section 3 we study the evolution of world natural gas production. In Sections 4, 5 and 6 we examine three local cases: Former Soviet Union (FSU), Italian and Great Britain natural gas productions. All the obtained results are compared with BP (British Petroleum) and USGS (United States Geological Service) forecasts. One intriguing aspect is related to the FSU reserves assessments. Section 7 is devoted to final remarks and discussion.

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