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Forecasting the coal production: Hubbert curve application on Turkey's lignite fields

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ABSTRACT

The dependence on imported energy sources is one of the biggest challenges that Turkey and many other similar countries face in the 21st Century and the gap between production and consumption cannot be decreased without increasing the domestic production. Forecasting of domestic energy production therefore plays a vital role in order to be able to develop sound energy policies towards maintaining sustainable development. However, although this question is essential in this respect especially for import dependent countries, the previous literature is surprisingly scarce. This paper, therefore, will be important for future studies on estimation of energy production. We first analyzed lignite production of Turkish Coal Enterprises (TKI) from a historical perspective and then forecasted the future production by using the Hubbert curve, depletion rate, and decline curve methodologies. We concluded that the largest fields are about to enter a declining phase of production in upcoming years and most of the reserves will remain untapped if business-as-usual continues in the future. The methodology and interpretations may be used by other developing countries, which deeply suffer from energy import dependency.

1. Introduction

One of the biggest challenges that Turkey faces in the 21st Century is the dependence on imported energy sources (e.g., Ediger, 2001, 2004; Çamdalı and Ediger, 2007; Ediger and Berk, 2011). In 2013, only 26.5% (31.944 Million tons-of-oil-equivalent, Mtoe hereafter) of total primary energy supply (120.290 Mtoe) was produced domestically and the net import dependency of the country was 72.3% (86.978 Mtoe).[1] This huge gap between energy supply and demand should definitely be decreased in order to mitigate the overburden of imported energy. Increasing domestic production while decreasing consumption by improving energy efficiency is obviously the best way to tackle this important problem. However, both solutions appear not to be readily available because of resource scarcity and the traditional inefficiency of the Turkish energy system. The sustainability of more than a decade of economic growth and development, fueled by the increasing energy consumption of the country, depends strongly on developing and implementing sound energy policies towards solving this problem (Ediger and Tatlıdil, 2002; Ediger, 2003). This problem and possible solutions are also applicable for similar developing countries, which deeply suffer from energy import dependency.

The country's coal endowment is the most plausible candidate for increasing domestic energy production in Turkey. By 2012, remaining recoverable reserves of oil and gas were 310.4 Mtoe and 7.1 Billion cubic meters (Bcm, hereafter), respectively, whereas the country has 12,152 Million metric tons (Mtonnes, hereafter) of proven lignite and 523 Mtonnes of proven hardcoal reserves (WEC-TNC, 2015).[2] Consistently, around half of the country's domestic primary energy production in 2013 was from coal. The share of total domestic production is 7.8% (2.485 Mtoe) for oil, 1.4% (443,000 toe) for natural gas, and 1.5% (488,000 toe) for asphaltite, whereas it is 43.7% (13,973 Mtoe) for lignite and 3.1% (990,000 Toe) for hardcoal. The overall share of fossil fuels is 57.5% (18.380 Mtoe) of domestic energy production, which is only 26.6% (31.944 Mtoe) of primary energy supply (120.290 Mtoe).

The purpose of this study is, therefore, to contribute to the policy-making processes towards increasing the domestic energy supply of the country by developing a forecast for Turkey's future lignite production.

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[1] According to the statistics provided by the Ministry of Energy and Natural Resources of Turkey (MENR), 5.497 Mtoe was exported mostly in the form of various oil products and 3.814 Mtoe was used as bunkers in 2013 (MENR, 2015).

[2] However, most recently, Ediger et al. (2014) concluded that reserve estimation practices in the country should definitely be revised to provide a more realistic evaluation of the country's lignite potential for developing medium- and long-term energy strategies and policies for decision- and policy-makers.

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Given the role of lignite in the Turkish energy system, forecasting future production becomes vital for the country's energy supply security. An estimate for Turkey's coal production in the long run would not only help to develop accurate investment planning for energy production/generation and distribution but would also be helpful for developing policies for alternative energy sources and for climate change as noted by Rutledge (2011). In fact the problem is global and the conclusions drawn from this study will be applicable in other similar countries in the world. At present, more than 20 countries have already reached a maximum capacity in their coal production, unlike China, which has the third largest coal reserves in the world, is the largest coal producer and consumer and whose coal production has not yet reached its peak (Lin and Liu, 2010).

Although, the questions regarding future energy production and the required imports are essential in this respect especially for import dependent countries, it is surprising that literature on energy supply forecasting is considerably limited compared with that on energy demand. In most countries energy forecasting is typically carried out for the demand side of energy systems and forecasts of both energy production and consumption such as the one carried out by Xiong et al. (2014) in China are rare.

Turkey is no exception. The studies on energy demand forecasting in Turkey date back to the 1960s and were mostly carried out by the State Planning Organization (SPO), the Ministry of Energy and Natural Resources of Turkey (MENR) and a number of academicians.[3] On the other hand, to the authors' best knowledge, Ediger et al. (2006) is the first study on forecasting production of fossil fuel sources in Turkey, including hard coal, lignite, asphaltite, oil, and natural gas from 1950 to 2003. In addition to this study, Toksarı (2009) estimated Turkey's net electricity energy generation and demand until 2025 based on economic indicators by using the ant colony optimization (ACO) approach. Çınar et al. (2010) estimated the production of hydropower until 2012 by using genetic algorithms (GA).

The current paper contributes to the energy supply forecasting literature by concentrating on the Turkish lignite industry and by using Hubbert's methodology[4] on the comprehensive lignite mine data of Turkish Coal Enterprises (TKI, hereafter). The structure of this article is as follows. Section 2 provides a review of the relevant literature. Section 3 explains the data employed in this study. The subject of Section 4 is forecasts of future production as well as the depletion and decline curve analyses. Finally, Section 5 concludes.

2. Methodology

2.1. Forecasting fossil fuel production

Literature on estimation of fossil fuel production started as early as 1909 and the quantitative understanding of oil depletion through calculating the exhaustion time of oil reserves and different methodologies have been applied to forecast fossil fuel production curves in many regions or countries in the world since then.[5] These methods have recently been grouped into two classes, namely, (1) Top-down: models that forecast aggregate production through some form of extrapolation of aggregate variables, such as simple curve-fitting, system dynamic simulations and macroeconometric models, and (2) Bottom-up: models that represent the supply chain of the upstream oil industry, and forecast aggregate production as the sum of production from smaller units (Jakobsson et al.., 2012, 2014). Moreover, Chavez-Rodriguez et al. (2015) divided oil production forecasting techniques into three main categories namely, the economic, the geophysical based, and the hybrid, which combines the first two approaches, aiming at explaining the deviations of the geophysical models from the historical production. On the other hand, Brandt (2010) after examining all methods concluded that "the greatest promise for future developments in oil depletion modeling lies in simulation models that combine both physical and economic aspects of oil production."

2.2. Hubbert curve methodology

Hubbert method is one of the top-down methods and as correctly noted by Saraiva et al.., "among them the curve-fitting models, especially the approach of Hubbert, are a simple and suitable tool for first-order projections of future production", "especially when data for ultimately recoverable resources (URR) are uncertain and producers are price-takers" (Saraiva et al., 2014).

M.C. King Hubbert, an American geophysicist, estimated the future US oil production in 1956 by using mathematical equations (Hubbert, 1956) and later related his graphical predictions for cumulative production over time to a logistic curve (Hubbert, 1959). His famous approximately symmetric, bell-shaped curve, which is now known as Hubbert's curve, and his methodology have been debated vigorously since then (Tao and Li, 2007; Bardi, 2009). Although the methodology was initially used for oil production, later it began to be applied for other fossil fuels such as natural gas and coal. Authors such as Ericsson and Söderholm (2010), Giraud et al. (2010), Vaccari and Strigul (2011), Giraud (2012), Rustad (2012), Zittel (2012), Scholz and Wellmer (2013), Scholz et al. (2014), and Vaccari et al. (2014) have attempted to use the Hubbert's method for various mineral commodities production and techniques. Ericsson and Söderholm (2010) noted that "the differences between oil and minerals should neither be overstated nor ignored." (p. 1) and "the most important difference is clearly the recyclability of minerals but from most other points of view the differences between oil and other minerals should not be exaggerated." (p. 2).

At present, Hubbert's curve is used for many purposes varying from predicting production at a global level to country level or even to field level. However, its most common usage has always been to determine the date of the global oil peak (e.g., Bentley et al., 2007; Bardi, 2009; Reynolds, 2014). Several modified forms have been used to determine ultimate oil recovery rates of production in various countries for several resources such as oil in the USA (Kaufmann, 1991; Cleveland and Kaufmann, 1991; Pesaran and Samiei, 1995), oil and natural gas in Denmark (Mackay and Probert, 1995), oil in Brazil (Saraiva et al., 2014), natural gas in China (Wang and Lin, 2014), natural gas in Algeria (Guseo et al., 2015), oil in Peru (Chavez-Rodriguez et al., 2015), oil in Norway and Denmark (Sällh et al., 2014), oil in the UK and Norway (Fiévet et al., 2015). On the other hand, Söderbergh et al. (2010) made a field-by-field study of 83 Russian giant gas fields in order to analyze future Russian natural gas production for European energy security. A good analysis of the performance of supply forecasting over the past two decades, including the methodological errors in the geophysical models and the difficulties of creating a valid microeconomic model can be found in Lynch (2002).

Mainly four assumptions are included in Hubbert's mathematical model, namely (1) yearly production is modeled as the first derivative of the logistic function, (2) production profile is symmetric, (3) production follows discovery with a constant time lag, and (4) production increases and decreases in a single cycle without multiple peaks (Brandt, 2010, p. 3959; Vaccari et al., 2014, p. 136). The validity of these assumptions was often criticized, but as Hubbert noted frequently in his publications, these were only simplifying assumptions to allow tractable mathematical analysis, not a reflection of reality

[3] Please see, Ediger and Tatlidil (2002) for a comprehensive literature review of demand forecasts in the Turkish energy system. Since then, various techniques have been applied in energy demand forecasting for Turkey, such as degree-day, linear and multivariate regression, autoregression, genetic algorithm, and artificial neural network (Ediger and Akar, 2007).

[4] Authors are aware of the intensive debate on the plausibility of the assumptions of Hubbert's methodology. Please refer to Section 2.2 for the literature review on this debate and the reasoning of the choice of this methodology in the current paper.

[5] For a comprehensive summary please refer to Brandt (2010) and Saraiva et al. (2014).