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Charting the Future Global Status of Oil and Natural Gas using Grey Forecasting

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Abstract: *This study adopts Grey Forecasting offering an alternative method of forecasting oil and natural gas production and consumption. The Accumulated Generation Operation (AGO) decreases the randomness of data which is one of its critical features. Employing the GM (1, 1) model, the results show that the world will face an oil deficit of 10 million barrels daily by 2025 and a gas surplus of 30 billion cubic meters. Policy makers are warned to change the existing increasing consumption practices for oil and natural gas as well as to seek new solutions for the short-term, medium-term and long term.*

Keywords: Energy economics, energy policy, grey forecasting, grey model, macroeconomic forecasting, world oil and natural gas production and consumption
JEL classification: C63, E23, Q47

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1. Introduction

Oil and natural gas are important sources of exhaustible energies which play a significant role in powering the world economy. Commercial energy is drawn from electricity, natural gas, crude oil and its refined products, coal and biomass energy products; without these types of energy, households' utility maximisation and firms' production are greatly compromised. In the case of transportation, currently none of the renewable energies can adequately replace fossil fuels as renewable energies are mostly converted into electricity. As a result, fossil fuels play a key role in transportation

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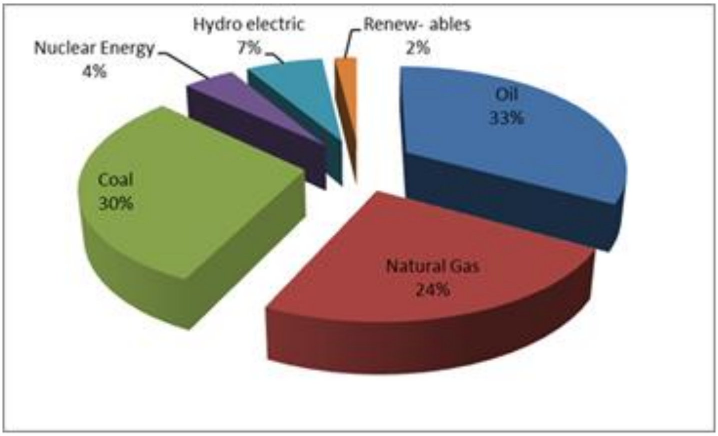
systems in the world. The International Energy Agency or IEA (2008) reported that conventional oil comprises more than 97% of world liquid fuel production. Conventional oil includes crude oil, condensate and natural gas liquids. It is also predicted that conventional oil will account for 90% of global liquid fuel production in 2030 (IEA, 2008).

Oil is an input for more than 2000 end products. Transportation and storage of oil are comparatively easy, an advantage for one of the most valuable commodities in world trade. It has also significantly shaped the share of profits and taxes for many economies in the world (O'Rourke & Connolly, 2003). However, there are concerns regarding the environmental consequences of rapidly increasing consumption of oil, which causes an increase in carbon dioxide emission. The main consequence of carbon dioxide emission is global warming. There were concerns regarding global warming since the late 1980s as a result of consuming fossil fuels. Countries became more aware of reducing greenhouse gas emissions and improvement of energy efficiency. More specifically, in 1997, at the third Conference of the Parties in Kyoto, countries agreed to reduce their greenhouse gas emissions from 2008-2012 relative to the 1990 levels. As a result, countries party to the Kyoto conference decided to increase their energy efficiency in all sectors of the economy (Ang, 2006). The other concern regarding oil is that the amounts of oil reserves are arguable and uncertain. It is not clear whether oil reserves can meet future ongoing demand (Owen, Inderwildi, & King, 2010). In the short-term, the production of crude oil seems unstable and even if the current levels of production continue to increase, it will be insufficient to meet the future growing demand of this non-renewable source of energy (De Almeida & Silva, 2009). On the other hand, some researchers believe that increase in the prices, new discoveries, enhanced recovery and the development of non-conventional resources such as oil sands may result in sufficient future production to meet ongoing demand (Adelman, 2003; Mills 2008; Odell 2004).

The IEA (2008) relates the increase in Gross Domestic Product (GDP) growth with the increase in the use of oil. Hirsch (2008) also showed that there is approximately a 1:1 correlation between decline in GDP and decline in the world supply of oil. These findings indicate the considerable effects of oil on the global economy. The share of fossil energy from total consumption of commercial energy in the world is 81%. Fossil energy also accounts for 98% of total energy which is used in the transportation sector in the world (De Almeida & Silva, 2009). In addition, data from the British Petroleum Statistical Review of World Energy shows that oil and natural gas have the largest share of primary energy consumption among different types of primary energy in the world for 2012. Reserve to production ratio (RPR) is 46 years for oil. This ratio is 52 years for natural gas (Vysotskii &

Dmitrievskii, 2009); consequently, the world will face a glaring gap between supply and demand for these two non-renewable resources.

Figure 1: Share of oil and natural gas in primary energy consumption in the World.



Source: British Petroleum (2013).

Even though many researchers predicted a near term peak of oil and then decline in production of this non-renewable resource, data shows that the consumption of oil is increasing over time. Furthermore, there is a concern about gas peaking which many researchers pointed out in their studies (Laherrere, 2003; Simmons 2007). Among all fossil fuels, conventional crude oil is the most important one and its depletion is more serious and crucial (De Almeida & Silva, 2009) as many economies greatly depend on this source of energy. As a result, despite the discovery of new oil wells, these non-renewable sources of energy are being increasingly exhausted as overproduction is rapidly depleting existing reserves (Campbell & Heapes, 2009; Campbell & Laherrere, 1998; Hubbert, 1949).

This study is anchored on the primary objective of applying the breakthrough grey theory forecasting method to generate more accurate forecasts of oil and natural gas production and consumption until 2025, as oil and natural gas form the core energy sources and drive the better part of global production lines; better planning is possible when more robust forecasts are generated. The reason behind considering oil and natural gas production and consumption as grey systems is that the relation between production and consumption of oil and natural gas and the factors which affect them is not clear. Moreover, it is difficult to select explanatory variables which affect production and consumption of these two vital sources of energies. In addition, the grey theory forecasting method has some advantages in comparison with the traditional forecasting methods like regression models such as requiring less volume of data, requiring no statistical tests and the assumptions of statistical distribution of data are not necessary when applying grey theory forecasting method. Hence, this study applies grey theory forecasting method to generate better forecasts of production and consumption of oil and natural gas.

This study is organised as follows: Part 1 as introduction, Part 2 briefly reviews the current status of world oil and natural gas production and consumption based on data from British Petroleum Statistical Review of World Energy and literature findings. A brief discussion of world oil and natural gas proven reserves have also been added. Part 3 discusses the methodology of research and relevant literature. Results are discussed and illustrated in Part 4 and the paper concludes in Part 5.

2. The Current Status of World Oil and Natural Gas Production, Consumption, and Proven Reserves

2.1 The current status of world oil production and consumption

Crude oil resources are limited and exhaustible and unlikely to meet future demand. As a result, oil market will soon change from demand-led to a supply constrained market (Owen et al., 2010). Jakobsson, Bentley, Söderbergh and Aleklett (2012) state that unconcerned groups support their view of the future availability of oil with an argument which is flawed. These groups state that there are still huge amounts of oil in the ground with low average production cost. The average production cost of oil does not determine price and output, as average cost is not equal to marginal cost. In addition, the specific cost structure of the oil industry including user cost must be considered (Jakobsson et al., 2012).

The first alarm regarding peak oil production was illustrated by a Shell oil worker in Houston using his famous bell-shaped curve (Hubbert, 1956), which became a famous introduction to this concept. His first prediction was about US peak oil production. Hubbert predicted that it would happen in the early 1970s and it did. Later on, geologists applied Hubbert's peak oil theory for oil production at the global level. Critics of Hubbert's curve state that this model has no explicit micro foundation in geology and physics nor in economic theory (Jakobsson et al., 2012). Campbell and Laherrere (1998) presented a seminal paper in 1998 in which they discussed a near-term peak oil production and predicted that it will happen before 2010. The modern discussion of peak oil problem (PO) has been mainly influenced by this paper which led to the forming of the Association for the Study of Peak Oil and Gas (ASPO) (De Almeida & Silva, 2009). Supporters of 'peak oil production' (Aleklett & Campbell, 2003) state that the term does not mean running out of oil, rather, it refers to scarcity of oil resources (Balaban & Tsatskin, 2010).

There were 507 giant oil fields in the world with 403 of them in active production operation in the 2005 (Robelius, 2007); of the 403 active oil fields, production in 261 of them has been on the decline since 2005 (Höök, Hirsch, & Aleklett, 2009). Owen et al. (2010) argued that the peak of discovery of conventional oil has already passed which was in the early of 1960s. Most of the discoveries were in 1948 and few have been discovered since the 1980s. They also pointed out that the consumption of oil has been increasing during that period (Owen et al., 2010). Sorrel, Speirs, Bentley, Brandt, and Miller (2010) stated that most of the world's oil fields were discovered in the period 1946 to 1980, so the peak of discoveries has already passed (Sorrell et al., 2010). In addition, Sorrell et al. (2010) used a three-year moving average to examine annual discoveries and also examined the cumulative discoveries for the period 1860 to 2010. They demonstrated that the annual discoveries of oil are decreasing over time. As a result, the world will face a shortage of this non-renewable resource in the future (Sorrell et al., 2010).

It is predicted that the world will soon face a near-term peak and decline in the production of conventional oil and that it will not be possible to fill this gap with alternative sources of energy (Aleklett, Höök, Jakobsson, Lardelli, Snowden, & Söderbergh, 2010). Sorrell et al. (2010) provided three main reasons for the future limitations of oil supply, which are based on "physical features of the resources". These reasons are as follows:

- Production of each field usually increases to its peak and after that it will decline because of falling pressure and/or "breakthrough of water". While every single field has its own characteristics and features, production normally starts to decline when half of the resource have been extracted and produced.
- Just a few large fields contain most of the oil in a region. For instance, 110 out of 70,000 oil fields in production provide half of the world oil supply.
- These large fields were discovered very early, as they occupy larger areas in comparison with small fields. As a result, the next few discoveries are expected to be smaller and require more effort to locate. For example, more than half of the world's giant oil fields were discovered 50 years ago.

Production from small oil fields that are discovered later is not sufficient to offset the decline in the production of large fields. More than 100 oil-producing regions around the world have shown this pattern; as a result, a severe shortfall at the global level will soon occur (Sorrell et al., 2010).

A review of all countries in the world in terms of production and consumption of oil, based on data from British Petroleum (BP) Statistical

Review of World Energy 2013, shows that the two largest oil producers in the world are Saudi Arabia and the Russian Federation which produced 11,530 and 10,643 thousand barrels daily that account for 13.3% and 12.8% of total world production in 2012 respectively. The United States and China are the largest consumers of this vital source of primary energy by consuming 18,555 and 10,221 thousand barrels of oil daily accounting for 19.8% and 11.7% of total world oil consumption in 2012 respectively.

Looking at the regions and based on data from BP on the production side, the Middle East is the largest producer of oil producing 28,270 thousand barrels daily in 2012. This amount is 32.5% of total world oil production. After the Middle East, Europe and Eurasia have the most production of oil among all the regions in the world producing 17,211 thousand barrels daily, which accounts for 20.3% of total world production in 2012. North America is third by producing 15,557 thousand barrels daily in 2012. This amount is 17.5% of total world oil production. Africa, Asia Pacific and South America together with Central America produce the rest of world oil contributing 10.9%, 9.6% and 9.2% of total world production in 2012.

Oil consumption based on regions shows that the Asia Pacific is the largest consumer of oil in the world in 2012 amounting to 29,781 thousand barrels daily, which is 33.6% of total world oil consumption. The second largest consumer of oil is North America consuming 23,040 thousand barrels daily in 2012, which is 24.6% of world's total consumption. The third largest consumer of oil is Europe and Eurasia consuming 18,543 thousand barrels daily in 2012, which is 21.3% of the world's total oil consumption. The Middle East, South & Central America and Africa are the next biggest consumers of the world's oil consuming 8,354, 6,533 and 3,523 thousand barrels daily in 2012 respectively. These account for 9.1%, 7.3% and 4.0% of total world oil consumption.

2.2 The current status of world natural gas production and consumption

The natural gas resources are more abundant in comparison with oil. The world oil discovery trend has been declining since the mid-1960s and geologists agree that it cannot change, but conditions appear to differ for natural gas. Mohr and Evans (2011) point out that world conventional natural gas production has been projected to peak before 2040 (Mohr & Evans, 2011). On the other hand, Bentley (2002) suggests production of conventional gas will start to decline from 2020 as that the world has reached 50% of global gas production levels and supply has exceeded demand for most of the last century. Most of the discoveries were between 1960 and 1980 with many of them in Russia, the Middle East, Netherlands and Indonesia. Goodstein (2004) argues that the rate of discovery of natural gas has fallen below its rate of consumption since 1980. For natural gas, the larger gas deposits are generally located sooner compared with oil. These large fields contain most of the world's natural gas reserves. As a result, there is a long term decline in the rate of discovery of natural gas resources (Bentley, 2002). In view of this fact, the production of natural gas is bound to decline in the future as it is a non-renewable resource.

The United States and the Russian Federation have the largest share of natural gas production producing 681.4 and 592.3 billion cubic meters of natural gas in 2012 respectively, representing 20.4% and 17.6% of the world's total production of natural gas. On the consumption side, as with the production side, the United States and the Russian Federation were the largest consumers of natural gas in the world in 2012 with 722.1 and 416.2 billion cubic meters of consumption respectively, accounting for 21.9% and 12.5% of total world consumption.

Regionally, Europe & Eurasia have the largest share of natural gas production in the world in 2012. Their share is 1035.4 billion cubic meters which represents 30.7% of global total production in 2012. The second largest regional producer of natural gas is North America which produced 896.4 billion cubic meters which equals to 26.8% of total world production in 2012. The third largest producer is the Middle East which produced 548.4 billion cubic meters accounting for 16.3% of total world production. The Asia Pacific, Africa and South & Central America produced the rest of the world's natural gas. They produced 490.2, 216.2 and 177.3 billion cubic meters respectively, accounting for 14.5%, 6.4% and 5.3% of total world natural gas production in 2012.

Europe & Eurasia have the largest share of consumption of natural gas compared with the rest of the regions in the world in 2012. Both these regions consumed 1083.3 billion cubic meters which accounts for 32.6% of total world consumption for 2012. Regionally, the second largest natural gas consumer in the world is North America, consuming 906.5 billion cubic meters or 27.5% of the total world consumption. The third largest consumer is Asia Pacific consuming 625.0 billion cubic meters accounting for 18.8% of total world consumption. The Middle East, South & Central America and Africa consume the rest of world natural gas. These regions consumed 411.8, 165.1 and 122.8 billion cubic meters in 2012 which account for 12.4%, 5.0% and 3.7% of the total world natural gas consumption respectively.

2.3 The current status of world oil and natural gas proven reserves

There have been debates and some confusion regarding the amount of oil reserves but there is less uncertainty about natural gas reserves. This is because large-scale commercial production of gas is recent and as a result, there are fewer weaknesses in historical definitions of reserves (Bentley, Mannan & Wheeler, 2007). The amount of reserves are constantly changing due to production and consumption as well as new discoveries and emerging new technologies which lead to increase in reserves.

The biggest proven oil reserves are concentrated in the Middle East accounting for 807.7 thousand million barrels in 2012, which is 48.4% of total world proven reserves. The second largest proven reserves are concentrated in South America & Central America which has 328.4 thousand million barrels of oil, accounting for 19.7% of total world proven reserves. North America has 220.2 thousand million barrels or 13.2% of world reserves while Europe and Eurasia have 140.8 thousand million barrels which accounts for 8.4% of global reserves. The remaining reserves are located in Africa and Asia Pacific (BP, 2013).

Looking at the natural gas proven reserves, Middle East dominates with 80.5 trillion cubic meters in 2012 accounting for 43.0% of total world proven reserves. Europe and Eurasia have 58.4 trillion cubic meters accounting for 31.2% of total world natural gas proven reserves. Asia Pacific with 15.5 trillion cubic meters accounts for 8.2%, Africa with 14.5 trillion cubic meters accounts for 7.7%, North America with 10.8 trillion cubic meters accounts for 5.8% while South & Central America have the rest of the world proven reserves (BP, 2013).

The biggest proven reserves of both oil and natural gas are concentrated in the Middle East, resulting in economic dependence of many countries around the world on supplies of oil and natural gas from a region which is not politically stable. Forecasting future production of oil and natural gas is challenging owing to political instabilities in the Middle East countries.

The above arguments address the key problem statement, which then leads to our prime objective which is to frame the future of energy economies and specifically, oil and gas economies, for an updated global outlook using a comparatively innovative methodology.

3. Methodology: Grey Forecasting

First created by Deng (1982), this innovative method of forecasting encapsulates a multidisciplinary and generic theory (Hsu & Chen, 2003) and has been adopted largely by engineers and scientists, and to a much lesser extent, by economists. The accumulated generation operation (AGO) is one of the most important characteristics of Grey theory with the objective of reducing data randomness. Deng (1989) explains that the Grey System’s goal is to bridge the gap between social science and natural science and it provides theory, techniques, notions and ideas for resolving and studying latent and intricate systems.

Hsu and Wen (1998) improved on the GM (1,1) model by using residual modifications with Markov-chain sign estimations for total passenger flows for 10 countries in the Asia Pacific region. Hsu and Chen (2003) use a modified Grey forecasting model for long-term prediction of power demand in Taiwan. Xie and Liu (2009) adopted a novel discrete grey model termed DGM to enhance the tracking ability. Yao, Forest, and Gong (2012) developed and expanded the fundamentals of Grey Systems, hence, solving the problem of non-equidistance grey prediction with integral or digital interval. Liu, Wang, Liu, and Li (2014) proposed a new PGRM (1,1) model with a rolling mechanism based Grey model optimised by particle swarm to enhance predictive power.

In its application, Zhou and He (2013) proposed a Generalized GM (1,1) model with a higher simulative ability than GM (1,1) and Discrete GM (1,1) Models for the forecast of fuel production in China. On the other hand, Tang and Yin (2012) applied Grey prediction for education and school enrolment in China. Kayacan, Ulutas, and Kaynak (2010) assessed the GM (1,1), Verhulst model and modified Grey models using Fourier Series on exchange rates and concluded that the modified Grey using Fourier series in time yields the best fit. Lu, Lin and Lewis (2007) looked at grey relation performance correlations between economics, energy use and carbon dioxide emission in Taiwan. Chang, Lai, and Yu (2005) employed the rolling Grey forecasting model for Taiwan’s semi-conductor industry production.

This study applies the grey theory forecasting method (Deng, 1982; Hsu & Chen 2003; Mostafaei & Kordnoori, 2012) in order to forecast future production and consumption of oil and natural gas to 2025. The advantage of the grey theory forecasting method in comparison with statistical methods is that the assumptions of statistical distribution of data are not necessary (Hsu & Chen, 2003). Comparing traditional forecasting methods like the regression model against the grey theory forecasting method reveals that traditional models require a considerable volume of data which is not necessary in application of the latter. In addition, statistical tests are required when applying traditional forecasting models which are not necessary in the grey theory forecasting method. These advantages of grey theory forecasting method cause its application to be easier and provide more accurate predictions compared to traditional forecasting methods. Specifically, this study used the grey theory forecasting method (Deng, 1982) to estimate future production and consumption of oil and natural gas.

Deng (1982) introduced the concept of grey systems. He categorised the variety of available systems in nature and human society into three types: white systems, black systems and grey system. The white system is a system with completely clear information. In addition, it has certain structures and clear parameters. Information in a black system is not clear at all (black box). If information in a system is partially clear or partially unclear, this system is called a grey system, which means a system with uncertain structures and parameters (Morita, Kase, Tamura, & Iwamoto, 1996). Morita et al. (1996) applied grey theory forecasting method in their study for interval prediction of annual maximum demand. The reason they applied this method is that the relation between the power demand (dependent variable) and independent variables such as weather conditions or business fluctuations is not necessarily clear but they affect power demand (Morita et al., 1996). Based on the study of Morita et al. (1996) and definitions of three types of available systems in the world, production and consumption of oil and natural gas can be considered as a grey system. The reason behind choosing the grey system premise for the production and consumption of oil and natural gas is that the relation between production and consumption of oil and natural gas (dependent variable) and factors which affect them (independent variables) are uncertain and unclear. Information regarding the reserves of oil in the ground is also not clear and it is difficult to predict them. Moreover, introducing new extraction technologies makes the system unclear and uncertain. In addition, it is difficult to select the explanatory variables for prediction of future production and consumption of oil and natural gas. Production and consumption of oil and natural gas are affected by political conditions such as instabilities in major exporting countries and the relation between them (production and consumption of oil and natural gas and political conditions) is neither obvious nor predictable.

There have been debates regarding future oil production between concerned and unconcerned groups. The concerned group says that the oil peak is happening now or that it will happen in the very near future but the unconcerned group says that there is no availability problem in the predictable future and hence, they do not accept the concept of peak oil production in the foreseeable future. The fraction which is reported as reserves is dynamic and changeable, meaning that in-ground reserves are declining due to production but reserve potential may increase using new extraction technologies or through new discoveries as well as a result of new economic conditions. Changes in reserves make the future production capacity unpredictable, uncertain and unclear (Jakobsson et al., 2012). As a result, information in this system is grey i.e. the information is partially clear and partially unclear. Natural gas consumption is also affected by many uncertain factors, which cause the relationship between this variable and influencing factors to be highly complex and non-linear. There is black and white information existing in this system. As a result, grey theory forecasting method can be used for the purpose of forecasting natural gas consumption (Xie & Li, 2009).

One of the most important features and characteristic of this model is the Accumulated Generation Operation (AGO). The AGO reduces the randomness of data, because the functions that are derived from AGO are fitted to the exponential functions (Hsu & Chen, 2003). One of the most useful grey forecasting methods is the GM (1, 1), which is a time-series forecasting model. In order to use the GM (1, 1) model, not all of the data has to be available, however, it is necessary to have at least four data points. Data should be chosen from equal intervals and in sequential order without ignoring a single data (Deng, 1982). The description of the GM (1,1) model is as follows:

The original data series is shown by:

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)) \quad (1)$$

(n is the number of observations)

Then the Accumulated Generation Operation (AGO) is as follows:

$$x^{(1)} = (x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \dots, x^{(1)}(n)) \quad (2)$$

Where

$$x^{(1)}(1) = x^{(0)}(1), and\ x^{(1)}(k) = \sum_{m=1}^{k} x^{(0)}(m)$$

$$k = 2,3, \dots, n \quad (3)$$

Now we can employ the GM (1, 1) method which relates to the following first order difference equation:

$$dx^{(1)}(k)/dk + ax^{(1)}(k) = b \quad (4)$$

The above equation (4) can be solved with the least squares method as follows:

$$\hat{x}^{(1)}(k) = \left(x^{(0)}(1) - \frac{\hat{b}}{\hat{a}}\right) \times e^{-\hat{a}(k-1)} + \frac{\hat{b}}{\hat{a}} \quad (5)$$

Where,

$$[\hat{a}, \hat{b}]^T = (B^T B)^{-1} B^T X_n \quad (6)$$

and

$$B = \begin{bmatrix} -0.5\left(x^{(1)}(1) + x^{(1)}(2)\right), & 1 \\ -0.5\left(x^{(1)}(2) + x^{(1)}(3)\right) & 1 \\ \cdots & \cdots \\ -0.5\left(x^{(1)}(n-1) + x^{(1)}(n)\right) & 1 \end{bmatrix} \quad (7)$$

$$X_n = [x^{(0)}(2), x^{(0)}(3), x^{(0)}(4), \dots, x^{(0)}(n)]^T \quad (8)$$

As a result, we can obtain $\hat{x}^{(1)}$from equation 5. $\hat{x}^{(0)}$ is the fitted and predicted series:

$$\hat{x}^{(0)} = (\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \hat{x}^{(0)}(3), \dots, \hat{x}^{(0)}(n), \dots) \quad (9)$$

and

$\hat{x}^{(0)}(1) = x^{(0)}(1)$

Then we apply the Inverse Accumulated Generation Operation (IAGO):

$$\hat{x}^{(0)}(k) = (x^{(0)}(1) - \frac{\hat{b}}{\hat{a}}) \times (1 - e^{\hat{a}}) \times e^{-\hat{a}(k-1)}$$

$$k = 2,3, \dots \quad (10)$$

Where $\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \hat{x}^{(0)}(3), \dots, \hat{x}^{(0)}(n)$ is called the GM (1,1) fitted sequence, and $\hat{x}^{(0)}(n+1), \hat{x}^{(0)}(n+2), \dots$ is called the GM (1,1) forecast values.

4. Results and Discussion

The findings of this study include forecasting future oil production, oil consumption, natural gas production and natural gas consumption up to 2025 using grey theory forecasting method and then predicting future production-consumption deficit/surplus for oil and natural gas. Using matrix of B, $\hat{a}$ and $\hat{b}$ can be calculated. For oil production $\hat{a}$ and $\hat{b}$ are 0.013 and 46,638.638 respectively; for oil consumption. 0.016 and 44,319.195; for natural gas production, 0.027 and 1,086.297 and for natural gas consumption, 0.026 and 1,085.132 respectively.

The following tables show the forecasted amounts of production and consumption of oil and natural gas until 2025 by applying GM (1,1).

Table 1: Oil production and consumption forecasting using GM (1,1) to 2025

Oil Production and Consumption Forecasting (Thousand Barrels Daily)		
Year	**Production**	**Consumption**
2013	88172.24	93900.68
2014	89345.49	95375.10
2015	90534.35	96872.67
2016	91739.03	98393.76
2017	92959.73	99938.73
2018	94196.68	101507.96
2019	95450.09	103101.83
2020	96720.18	104720.73
2021	98007.17	106365.04
2022	99311.28	108035.18
2023	100632.75	109731.54
2024	101971.80	111454.53
2025	103328.67	113204.58

Source: Authors.

Table 2: Natural gas production and consumption forecasting using GM (1,1) to 2025

Natural Gas Production and Consumption Forecasting (Billion Cubic Meters)		
Year	**Production**	**Consumption**
2013	3442.32	3424.91
2014	3535.00	3516.83
2015	3630.18	3611.21
2016	3727.92	3708.13
2017	3828.29	3807.64
2018	3931.36	3909.83
2019	4037.21	4014.76
2020	4145.91	4122.50
2021	4257.53	4233.14
2022	4372.16	4346.75
2023	4489.88	4463.40
2024	4610.77	4583.19
2025	4734.91	4706.19

Source: Authors.

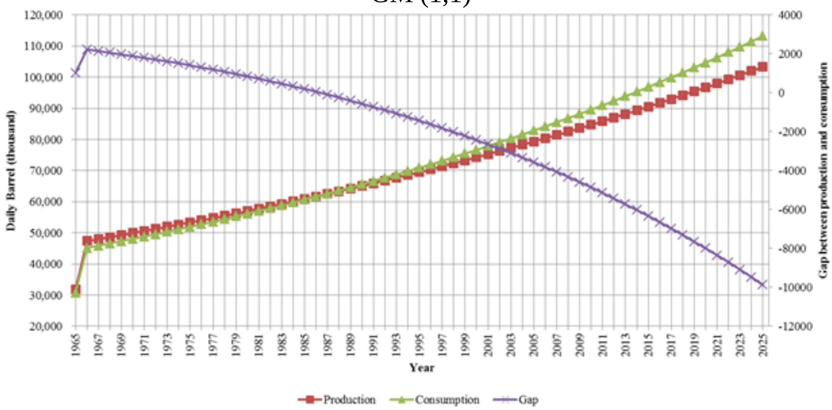
Table 1 shows that production of oil will increase to 103328 barrels daily in 2025. Oil consumption is estimated to increase to 113204 barrels daily in 2025. Results also show that the production of natural gas will increase from 3442 billion cubic meters in 2013 to 4734 billion cubic meters in 2025. Natural gas consumption is forecasted to be about 4706 billion cubic meters by 2025. The forecasted amounts of natural gas production and consumption are shown in Table 2. Table 3 and Figure 2 illustrate the deficit or surplus between production and consumption of oil for the period 1965 to 2025 using GM (1,1). Figure 2 shows that for the period 1965 to 1986 there was surplus with production exceeding consumption. This surplus amounted to 1023 barrels daily in 1965 falling to 50 thousand barrels daily in 1986. From then on and up to 2012, there were deficits indicating that the demand for oil has been continuously increasing parallel to expanding economies during this period. This gap increased from 1986 to 2012, reaching 5434 thousand barrels daily in 2012. Based on the results from grey theory forecasting method, it is predicted that the oil production-consumption difference will be negative for the period 2012 to 2025, reaching -9875.92 thousand barrels daily in 2025. We thus envisage a supply-side shock in the near future.

Table 3: Forecasted production-consumption deficit/surplus for oil and natural gas to 2025

Year	Oil Production-Consumption Deficit/Surplus (Thousand Barrels Daily)	Natural Gas Production - Consumption Deficit/Surplus (Billion Cubic Meters)
2013	-5728.43	17.40
2014	-6029.61	18.17
2015	-6338.32	18.97
2016	-6654.73	19.79
2017	-6978.99	20.64
2018	-7311.27	21.53
2019	-7651.73	22.45
2020	-8000.54	23.40
2021	-8357.87	24.39
2022	-8723.89	25.42
2023	-9098.79	26.48
2024	-9482.73	27.58
2025	-9875.92	28.72

Source: Authors.

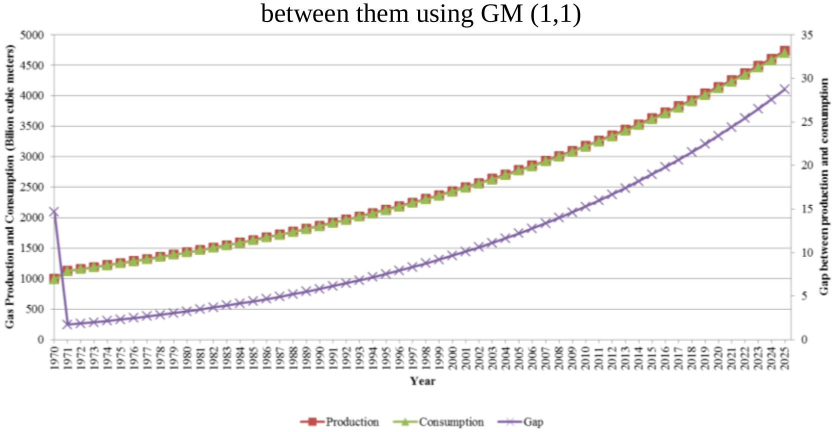
Figure 2: Oil production, consumption and the gap between them using GM (1,1)



Source: Authors.

Table 3 and Figure 3 show the production-consumption surplus for natural gas for the period 1970 to 2025, using GM (1,1). There is a consistent surplus during the period 1970 to 2025. This surplus was 14 billion cubic meters in 1970 but it dramatically decreased in the following year (1971) to around 2 billion cubic meters. Post-1971, this surplus gradually increased reaching 16 billion cubic meters in 2012. It is predicted that the production-consumption surplus for natural gas will increase from 2012 to 2025 and will touch 28 billion cubic meters by 2025. Correlating this finding with the deficit of oil suggests that substitution of oil with natural gas is a viable short-term solution for energy requirements.

Figure 3: Natural gas production, consumption and the difference (surplus) between them using GM (1,1)



Source: Authors.

This paper used error percentages in order to show the validity of application of grey theory forecasting method for the purpose of forecasting future production and consumption of oil and natural gas. Using historical data for production and consumption of oil and natural gas, results indicated that the average yearly error percentages of the GM (1,1) for oil production is 5.25%. For oil consumption, the average yearly error percentages of GM (1,1) is 4.59%. For natural gas production and consumption, the average yearly error percentages applying GM (1,1) are 2.13% and 2.02% respectively.

Forecasting method validation indicates that applying grey theory forecasting method for the purpose of predicting future production and consumption of oil and natural gas has minimal error and can produce reliable results. Table 4 shows Root Mean Square Error (RMSE) of GM (1,1) for oil production and consumption and for natural gas production and consumption respectively.

Table 4: Root mean square error percentage of GM (1,1) for oil and natural gas production and consumption.

RMSE	**GM (1,1) Model**
Oil Production	0.82%
Oil Consumption	0.77%
Natural Gas Production	0.26%
Natural Gas Consumption	0.25%

Source: Authors.

Stigler (1964) stated that secret cheating by firms happens in a cartel which makes the cartel unstable. This secret cheating occurs despite initial agreements to limit output. In the oil industry, political conditions such as sanctions can be the reason for cheating by the supplying countries. Cheating in an oil cartel depends heavily on the oil price. When the oil price is lower than what suppliers have expected, they start to produce more than their quota to offset the low price and reach their purposed budget, but when the price is higher than their expectations they do not produce more than their quota (Stigler, 1964). Kaufmann, Bradford, Belanger, Mclaughlin, and Miki (2008) argued that quotas should determine the production of OPEC members, otherwise OPEC would just be a trade organisation of competing producers (Kaufmann et al., 2008). Alhajji and Huettner (2000) stated “even after 1983, members did not follow their quota” Since OPEC producers do not follow their own quotas, the world oil production statistics cannot be wholly reliable as these countries do not release their real production statistics. This may be the reason for deficits between production and consumption of oil statistics.

As this study is about natural sources of energy, one of the limitations is the lack of geological knowledge. As a result, the forecasted results of production and consumption of oil and natural gas is not according to geological knowledge. Flaws and major drawbacks of time series analysis are the other limitations, as the method of prediction is the grey theory forecasting method which is basically a time series forecasting method. In addition, future political instabilities in major exporting countries and emerging new sources of energies and new methods of extractions can significantly affect production and consumption of oil and natural gas which are not considered in this study. Furthermore, oil and natural gas statistics are uncertain data sets which affect the forecasting of future production and consumption of oil and natural gas.

5. Conclusion

This study provides the current picture of production and consumption of two non-renewable sources of energy, oil and natural gas. In addition, this study forecasts the future production and consumption of these two exhaustible sources of energy and the resultant deficit/surplus up to 2025. The reason behind the application of grey theory forecasting method in this study is that the production and consumption of oil and natural gas can be considered as grey systems. In addition, it is difficult to select the explanatory variables which affect production and consumption of oil and natural gas. Results show that the gap between production and consumption of oil will increase from 2012 to 2025 and will reach −9875 thousand barrels daily by 2025. For natural gas, there will be a slight surplus in 2025. The production-consumption surplus for natural gas is expected to increase. Supply side shocks are expected to impinge on production chains and policies should address three primary factors:

1) Alternative energy as substitutes (as a short run policy).
2) Renewable energy substitutes (as a medium term policy).
3) Shifting technological frontiers (as a long run policy).

Considering the findings of this study, as there will be a surplus between production and consumption of natural gas, substitution of oil with natural gas for the purposes of heating and transportation can also be a good policy option in the short run. Renewable energies (medium term policy) are still costly, especially in the case of solar and wind energy generation, as these involve high investment costs. However, in a few cases, these methods have proven competitive such as the use of Brazilian biofuels and US onshore wind in the best locations (BP, 2012). There are many factors that motivate policy makers to devise policies designed to increase investment in renewable energy technology. The major reasons are as follows:

- While there is general awareness of the exhaustibility of oil and natural gas, we bring attention to the speed at which the divergence between production and consumption is occurring and suggest the possibility that the current rate of alternative energy technology creation may be inadequate
- The volatility in price of oil as a result of rapidly growing demand and shifting markets affect many economies around the world. Although renewable energies are still expensive, oil price increase causes the investments in renewable energies to be more cost effective.
- The effects of carbon dioxide emission on environment are harsh and the main reason for global warming as societies continue consuming fossil fuels especially in their transportation systems. Prevalence of renewable energies will cause the decrease in carbon dioxide emission.
- Economic dependence of many countries around the world on crude oil which is produced in politically unstable countries. These countries are mainly located in the Middle East.

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