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ORIGINAL ARTICLE

Study of Caspian energy markets via a hybrid index for energy demand security in Caspian countries in years 2020 and 2030

S. Vedadi Kalanter[1,2] · A. Maleki[3] · A. Saifoddin[1,2]

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Abstract
Establishment of demand security is a key incentive to boosting oil and gas investments in countries, thus, making the study of demand security also critical. In the present research, the primary aim is to explore the capacity of Caspian Markets in establishing energy demand security in the Caspian region and investigate its impact on oil and gas exports from the region. Therefore, additional factors such as political issues, international support and geographical limitations should also be considered for the determination of energy demand security. To address this need, a hybrid index is proposed that characterizes energy demand security in the Caspian region. In this research, we have looked at the countries of the Caspian region as a collective identity and we have avoided looking at the particular country of the Caspian region. In this study, we have used analytic hierarchy process (AHP method) to make hybrid index (Caspian energy demand security index). Results produced by the hybrid index demonstrate the superior state of Iran and Russia's swap markets in establishing demand security in the Caspian region in the years 2020 and 2030 when compared to the markets of China, European Union (EU) and India that follow, respectively. The exception to this trend is that in 2030, the European Union will demand more Caspian gas than China.

Keywords Caspian energy markets · Hybrid index · Energy demand security · AHP method

Introduction

The Caspian Sea, with energy reserves summing up to around 48 billion barrels of crude oil and 292 TCF of natural gas, plays a crucial role in supplying world energy. Moreover, approximately 20 billion barrels of crude oil and 243 TCF of natural gas remain yet undiscovered in the Caspian sea (EIA 2016). Nevertheless, oil and gas productions in the Caspian region face majorobstacles that hinder the course of its development. Lack of accurate analysis for current and potential Caspian markets is one such factor that heavily impacts the role of Caspian region in world energy exchange. Consequently, Caspian countries,[1] as influential world energy exporters that seek to attract foreign investments and earn greater shares of the market, are urged to perform accurate analyses on the future of energy markets and their respective states in the establishment of demand security. This research tries to investigate the situation in Caspian energy markets in the 2 years 2020 and 2030. Here, the aim is to create decision-making possibility for Caspian region countries with respect to energy demand security in the Caspian region. Formulation of an index for energy demand security lays the platform for exploration and evaluation of Caspian energy markets concerning the establishment of energy demand security in the Caspian region. Evaluation of Caspian markets and determination of their respective roles on the issue of demand security informs Caspian region policy-makers about markets that exhibit superior capability for establishing demand security in the region. The present research develops a quantitative hybrid index that analyzes existing markets (so far, such an index

✉ S. Vedadi Kalanter
saeed.vedadi@ut.ac.ir

1 Department of Renewable Energies and Environment, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran

2 Soft Technologies Research Institute, University of Tehran, Tehran, Iran

3 Department of Energy Engineering, Sharif University of Technology, Tehran, Iran

[1] Caspian countries are Azerbaijan, Kazakhstan, Iran, Russia and Turkmenistan but in this research, we have looked at the countries of the Caspian region as a collective identity.

has not been developed for the Caspian markets) in terms of demand energy security for the first time.

Literature review

Energy security research is conducted under two categories; namely, supply security and demand security. In this section, we will review literature in the quantification of energy supply and demand security.

Energy supply security

The need for a secure and sustainable energy flow by developed countries and advancements in the field of sustainable energy supply led to the concept and subsequently literature of "energy supply security". A host of scientists and theorists has since then strived to elucidate this concept and accordingly propose appropriate measurement indexes or indexes for the arrangement of policies aimed at energy supply and economic growth. Adjusting end use to fit supply constraints is essential for energy security (Fulhu et al. 2019). Energy supply diversification would improve the energy supply security. It would mitigate emissions of greenhouse gases and local/regional air pollutants (Shakya and Shrestha 2011).

Martchamadol and Kumar presented an integrated index for measuring energy security performance. The index was composed of 25 indexes that take into account various aspects of the problem such as economic, social and environmental aspects, simultaneously (Martchamadol and Kumar 2013). To create this index, a nine-step algorithm was designed that allowed all 25 indexes to undergo their respective preparation phases, including data collection, standardization [normalization], correlation test, grouping and creating a linear combination of correlated indexes, group weighting, scaling and finally, problem formulation. Martchamadol and kumar then proposed the following final relation (Eq. 1) for the index:

$$\mathrm{AESPI}_j = \sum (w_k \times \mathrm{GL}_{kj}) / \sum w_k, \tag{1}$$

where AESPI_j is the energy security integrated index in the jth year, GL_{kj} is the kth group index for the jth year and W_k is the weight of the kth group index. The output of this relation was a number scaled between 0 and 10, where higher numbers indicated better energy security states. To conclude, the authors compared the proposed index with a number of existing indexes and attempted to elucidate its relative advantages. Simplicity in computation, integrity, agreement in expressing various aspects of the problem and dynamic elucidation of the state of the problem were a number of such advantages associated with the index proposed in this work.

Chalvatzis and Ioannidis (2017) assessed the security of energy supply in all EU countries. They used proxy indices for variability and concentration of the Shannon–Wiener index and the Herfindahl–Hirschman index, and dependency criteria for the main energy fuel mix of all EU member states. This study shows the different relationships between dependency and diversity and the renewable role in dependency and diversity.

deLlano-Paz et al. (2016) analyzed the latest goals of the Energy Union using Markowitz's portfolio theory, taking into account the real assets of technology. This study seeks to ensure the new effects proposed by the European Commission in 2030 on the cost and risk of European energy production and the convenience of the various objectives included in the announced policy of the European Energy Union. For this purpose, each environmental goal is considered separately and side by side to facilitate the analysis of different policies.

Energy demand security

Energy demand security has received far less attention as compared to energy supply security. The needs of developed countries for secure and sustainable energy flow in addition to their efforts for preventing energy supply risks have led to more supply than demand security studies conducted so far. Energy demand security means guaranteeing the demand and sale of energy for energy exporting countries. For example, Iran by supplying almost all kinds of energies, is not facing serious problems with energy supply, but the demand side has some problems such as acceptability and accessibility (Solaymani 2020). However, oil and gas exporting countries and organizations (e.g., OPEC) have started conducting research that aims to explain and expand on the concept of demand security and its quantification in recent years.

Narula and Reddy created a multi-dimensional hybrid index to quantitatively evaluate the energy demand subsystem in India (Narula and Reddy 2016). This hybrid index comprised of 23 individual indexes that were selected based on availability, affordability, efficiency and acceptability criteria and was used to evaluate the different energy sectors in India in 2002, 2007 and 2012 as three timepoints of interest.

The hybrid index of this work was created with the aid of hierarchical energy system structure in India and targeted values in each sub-system (required for calculation of index scores) via conceptual values in that sub-system based on interviews with experts and specialists (required for calculating index weights). Results of this research demonstrated 10% performance improvement in the energy demand sub-system in India in the 2002–2012 timespan. Nevertheless, the performance of the energy demand sub-system in 2012 exhibited a value of 0.7 according to the hybrid index output, a value that was far from the ideal value of 1 by 30%.

Dike studied energy demand security in OPEC oil and gas exportation (Dike 2013). In this work developed two indexes for risk of energy exportation security as follows: (1) Risky Energy Export Demand (REED), (2) Contribution to OPEC Risk Exposure (CORE). The first index includes items such as dependency on exportation, economic dependency, risks of importation monopoly and transportation risk. The second index includes the share of each country in OPEC risk.

Muangjai et al. (2017) have changed the sensitivity of energy demand, which has changed from price and income. They used quarterly time series data to examine price patterns and revenue elasticity of demand for petroleum products for Thailand, and focused on the impact of gasoline and diesel subsidies through the 2004 energy price crisis. Finally, in the semi-subsidized oil price period (2011–2016), all petroleum products were elastic, indicating consumer adjustment after the price subsidy period.

Caspian energy markets

Based on the reports released by the American Energy Information Administration (EIA) for exports of energy from the Caspian region, markets of China, India, EU, swap with Iran and swap with Russia constitute the Caspian energy markets of interest in this research. Energy exported to the Iranian and Russian swap markets will eventually reach markets in China, India and the EU and China and the EU, respectively. In other words, swap markets act as links between the Caspian region and major world energy markets; therefore, Caspian region energy demand is influenced, both directly and indirectly, by markets of China, India and the EU (EIA 2016).

State of energy markets

China

Nowadays, China is one of the most important countries playing a big role in shaping future energy thorough the world. China's belt and road strategy is stretching across most of the globe and promises increased connectivity and economic development (Williams 2019). China's energy demand as the world's largest energy consumer and continued high economic growth, over the past decade, imply

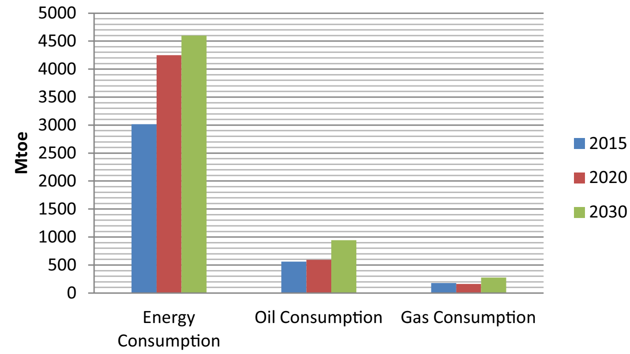

Fig. 1 Energy, oil, natural gas consumption in China market. Source: Statista 2015 and Berkeley Lab, China energy and emissions paths to 2030

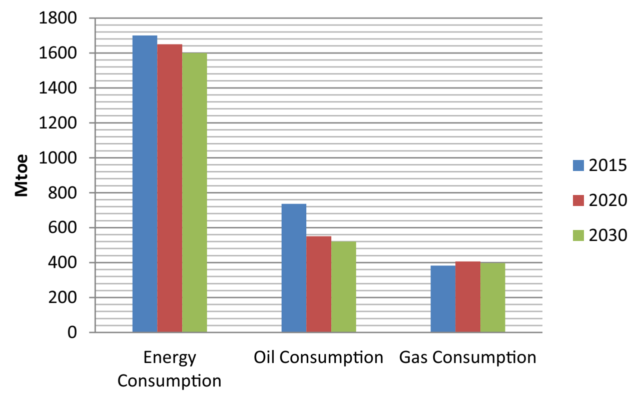

Fig. 2 Energy, oil, and natural gas consumption in EU. Source: European Commission 2016 and Europe Commission, Trends to 2050

its important role in making energy market development. Current outlooks indicate the continued need for energy consumptions and imports, thus making China the target of several energy export projects. In Fig. 1, china's energy demand, oil and gas consumption are specified in 2015 and 2 years 2020 and 2030.

China's energy demand grows 41 and 52 percent compared to 2015, respectively, in 2020 and 2030. In addition, China's energy consumption will reach 4600 Mtoe by 2030 and 3014 Mtoe by 2015. Also, oil and natural gas demand are 559.7 and 177.6 Mtoe, respectively, in 2015. Oil and gas demands are 592 and 161.8 Mtoe, respectively, at 2020 year indicating oil demand increase 5.7 percent and gas demand decrease 9 percent, respectively, in comparison to 2015. Oil and gas demand is 945.4 and 274.4 Mtoe at the time horizon 2030, which will be 69 and 54.5 percent more than in 2015. The growing trend of energy consumption, especially oil and gas carriers, makes all sellers and exporters of the energy carriers to pay attention to the China market as a reliable market for the long run.

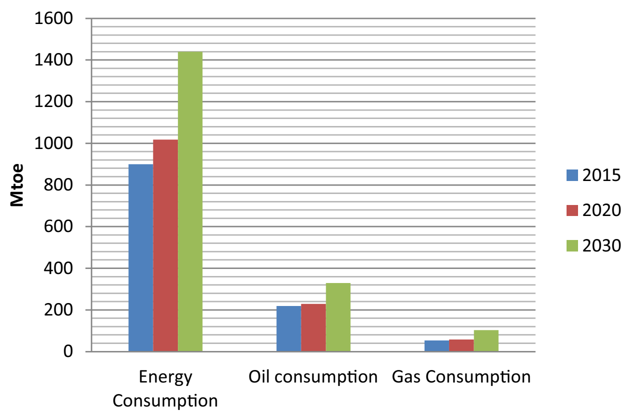

Fig. 3 Energy, oil, and natural gas consumption in India. Source: IEA oil market report 2015 and India Energy Outlook 2040

European union

Analysis of the procedure of consumption and import of energy in the European Union energy market, especially the utilization of oil and natural gas, is essential for exporter of both energy carriers (Vedadi et al. 2018). As depicted in Fig. 2, the use of oil and natural gas in the European Union, in 2015, are 735 and 353 Mtoe, respectively. Also, in 2020 and 2030, European Union oil consumption is 551 and 520 Mtoe, respectively, while natural gas consumption is 406 and 397 Mtoe. As mentioned earlier, the European Union seeks to decline fossil fuel utilization due to its policy concerned with environmental issues and diversifying energy primary resources.

India

Nowadays, India, as one of the five emerging economies and members of the Brix Group, is the world's largest industrial pole which has further increased India's energy demand (Vedadi et al. 2019). As shown in Fig. 3, India's primary energy demand has been on an upward trend. Therefore, based on the new policy scenario, energy demand in India is estimated at 900, 1018 and 1440 Mtoe in 2015, 2020, and 2030, respectively. In 2015, India's oil and natural gas demand is 219 and 54 Mtoe, respectively, which makes India the world's third-largest energy consumer after Japan (IEA 2015). Nowadays, it has a much-growing oil demand due to economic development and high energy demand in its factories and automotive sector. According to Fig. 3, India's oil and gas demand will be 229 and 58 Mtoe, respectively, in 2020 where the growth of 4% for oil demand and 7.5% for natural gas demand could be observed compared to 2015. Also, in 2030, India's oil and gas demand will be 329 and 103 Mtoe which face the growth of 50%, for oil demand, and 90%, for natural gas demand compared to 2015.

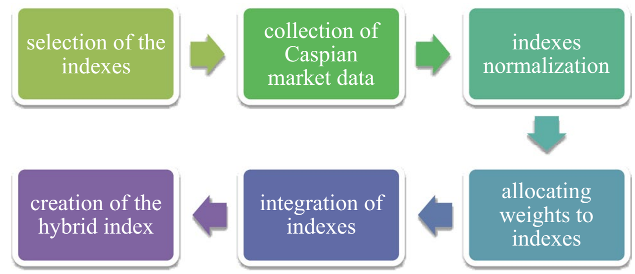

Fig. 4 Steps involved in data collection and creation of the hybrid index in the present research

Materials and methods

Methodology

In this research, a hybrid index is developed for energy security in the Caspian region to evaluate and analyze Caspian markets in terms of energy demand security. Figure 4 outlines the steps required in creating the proposed hybrid index.

Index selection

In this research, economical, geographical, political and technological criteria are taken into account for develop the energy security hybrid index. This choice is directly influenced by conditions governing the Caspian region including restricted and closed geographical borders, international support, international interferences with energy transfers in the region, and the unique conditions underlying the Caspian markets. Crude oil and natural gas contribute to the majority of exports from the Caspian region. So, these two energy carriers are examined independently for creation of the hybrid index where possible. With the aid of comparative studies and interviews with experts in the fields of energy security and Caspian Sea, ten indexes were selected under the four criteria given above (Table 1). If the number of used indexes is low, the energy security index will be very sensitive to the change in each index. A change in the index level may lead to a huge change in the composite index and ultimately cause the instability of index. Conversely, if the number of used indexes is high, the change in the individual indexes probably is neutralized by the majority of the unchanged indexes. A set of 10–25 indexes seems logical, because it means the average weight for each index is from 4 to 10% (Ang et al. 2015).

Data collection from the Caspian market

In the present research, five separate scenarios are developed to investigate the status of Caspian markets in the 2 years 2020

Table 1 Scopes and indexes considered for development of the hybrid index in the present research

Index	Independent examination of oil and gas reserves		Scope				Description	Formula
	No	Yes	Technological	Geographical	Political	Economical		
Energy diversification	✓					✓	This quantity can be calculated for Caspian markets using the Shannon–Wiener index	$SWI_i = -\sum_j P_i LnP_i$ *
Neid (Net energy import dependency)	✓					✓	This index demonstrates economic dependency on energy imports from the Caspian markets	$NEID = \frac{\sum m_i \times P_i \times \ln P_i}{\sum P_i \ln P_i}$**
WTP (Willingness to pay)		✓				✓	This index measures the tendency for payment in an attempt to preventing endangered supply security	$IMP_{t,r} = A_r\left(\frac{i_{t,r}}{i_{0,r}}\right)^{\alpha}\left(\frac{c_{t,r}}{c_{0,r}}\right)^{\beta}\left(\frac{E_{t,r}}{E_{0,r}}\right)^{\gamma}$, $\alpha = 1.1, \beta = 1.2, \gamma = 1.3$***
Energy consumption		✓				✓	With the aid of this index consumable energy can be determined for each of the Caspian markets	Energy consumption
Reserve to consumption ratio		✓				✓	With the aid of this index the resource-to-consumption ratio can be determined for Caspian markets in different time horizons	R/C
Economic growth	✓					✓	This index determines the economic growth in each of the Caspian energy markets	Economic growth
Development of technology	✓		✓				This index indicates the ability and potential of the energy market for creating added value via energy imports and subsequently using it	R&D share of GDP
Political consistency	✓				✓		The United Nations human development index is used to quantify political stability in each of the Caspian markets. This index is about political stability within Caspian countries	Human development index (HID)
International support	✓				✓		This index estimates international support for each of the energy transfer routes quantitatively	SWOT Method
Energy transfer geography	✓			✓			This index determines the geographical status of each of the energy transfer routes quantitatively	SWOT Method

*P_i is I carrier share of TPES

**P_i is I carrier share of TPES and m_i is I carrier share of energy import

***$I_{t,r}$, $C_{t,r}$ and $E_{t,r}$ are, respectively, import, consumption and energy intensity in time t and region r. In the case of non-dependence on imports, this index is zero. A_r is region-specific calibration constant. The function is calibrated based on the investments nations have made to improve their energy security in the past. We consider Caspian markets investment in renewable energy for function calibration and 2030. This is due to availability of the required data for each index in the various outlooks and scenarios of each market. For instance, energy consumption index is presented with the Reference Scenario in the International Energy Agency 2030 outlook whereas the political stability index is presented with the HIV Case Base Scenario in the United Nations Human Development outlook in the same year. Due to the inherent differences in these two scenarios, an independent scenario is devised for each market in accordance with the outlooks of the particular research indexes. References for data extracted from each market are given in Appendix 1.

China's market scenario

At the same time as sustaining its long-term renewable energy and environmental protection plans, China takes its current trend in energy demand and imports forward. China's economic development also follows this trend. The country's life expectancy and literacy levels are rising, but at a rate that is decreasing over time. Finally, China's fossil energy resources will not further increase as of the year 2015 and its share for research allowance as a technological development index will rise to 3% of the gross domestic production in the year 2030.

India's market scenario

In accordance with its previously reported plans, India takes steps forward towards enhancing its renewable energy resources and reducing its consumption of fossil energy. However, the country remains as one of the major importers of energy today and its economic growth also follows this trend. Life expectancy and literacy levels are rising in India but at a rate that is decreasing over time. India's fossil energy resources will not further increase as of the year 2015. Finally, the growth of India's technological development index will remain at the current trend.

EU's market scenario

Despite its investments in renewable energies, the EU supplies a great proportion of its energy needs via fossil energy resources. EU's economic growth follows this trend, respectively. Life expectancy and literacy levels are rising in the EU at a constant rate over time. Finally, EU's fossil energy resources will not further increase as of the year 2015 and its technological development growth is lower than China.

Iran's swap market scenario

Iran exports the oil and gas received via swap agreements with Caspian region countries to China, India and the EU as its three ultimate destinations. International support for energy swap between Caspian region countries and Iran is as indicated in the year 2015 and will not undergo any change until the year 2030. The rise in life expectancy and literacy levels are indexes of Iran's political stability index and the country exhibits the highest level of stability amongst Caspian region countries and markets in the 2020–2030 time interval.

Russia's swap market scenario

Russia exports the oil and gas received via swap with Caspian region countries to China and the EU as its two ultimate destinations. International support for energy swap between Caspian region countries and Russia is as indicated in the year 2015 and will not undergo any change until the year 2030. Life expectancy and literacy levels are indexes of Russia's political stability index that although follows a rising trend, will still remain less than Iran.

Political stability, international support and geography indexes are independent swap market indexes for both Iran and Russia. These are indicated in Appendix 1 according to references related to the respective scenarios. On the other hand, estimation of the indexes that are dependent on the export destinations require estimation of the hybrid index in the absence of swap markets for China, India and EU as a first step which is then followed using weighted average of the hybrid index results for estimation of indexes dependent on the swap markets based on the relevant scenario for each of these markets.

Normalization: minimum–maximum method

In this research, the minimum–maximum method is used for normalization of the indexes. The minimum–maximum method is the most popular tool used in energy security studies conducted between the years 2000 and 2014 (Ang et al. 2015). The vast majority of studies that aim to compare the performance of countries in the field of energy security use this method for normalization of the energy security index. For instance, Cabalu (2010) applied this estimation method for normalization of the relative indexes used for measuring the security of gas supply in countries. In this method, a number is estimated as given in the two depicted functions for each market via determination of the least and most values for data of a specific index. If the effect of the index on the resulting hybrid index is positive, Eq. (2) is used whereas if the effect is negative, Eq. (3) is used instead:

$$X_{im} = \frac{I_{im} - \mathrm{Min}(I_i)}{\mathrm{Max}(I_i) - \mathrm{Min}(I_i)}, \tag{2}$$

$$X_{im} = \frac{Max(I_i) - I_{im}}{Max(I_i) - \mathrm{Min}(I_i)}. \tag{3}$$

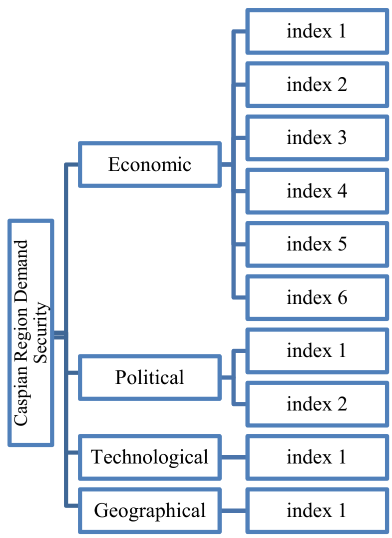

Fig. 5 Tree diagram of AHP methode

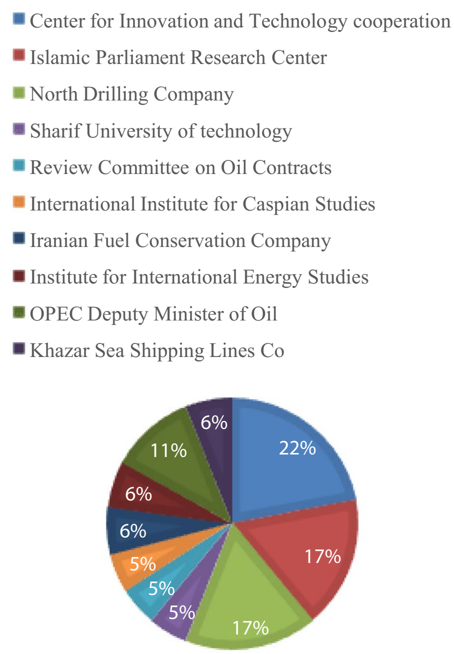

Fig. 6 Expert's dispersion in completing the questionnaire

Table 2 Weighting methods and normalization methods combination in energy security studies since 2000 to 2014 that has led to construct composite index

Weighting method	Normalization method			
	Min–max	Distance to reference	Standardization	Others
Equal weights	2	–	2	5
Fuel share/import share	1	–	–	3
PCA	3	–	1	–
AHP	1	–	–	–
Others	3	2	1	1

Weighting: analytic hierarchy process method

Economical, political, technological and geographical issues are the four criteria covered in this research. A number of indexes are allocated to each criterion. As evident from Fig. 5, pairwise comparisons are performed by the Analytic Hierarchy Process method between the four criteria and also between their corresponding indexes. Ultimately, the importance or weight of the indexes with respect to each other is determined based on the rationale governing the AHP method.

Weighting and normalization methods in energy security studies since 2000–2014 that has led to construct composite index are according Table 2 (Ang et al. 2015).

The weighting method is simple but in this method, there is no distinction between the importance of the indexes. The fuel/import share method takes into account the relative importance of each fuel type in energy mix or imports but it is clearly not suitable for non-fuel indexes. The principle component analysis (PCA) method corrects overlapping between correlated indexes and the importance of indexes is not considered. Analytic hierarchy process (AHP) is based entirely on expert opinions.

The fact that the allocation of weighting method is the most used method in energy security studies does not necessarily mean that it is the best method but, considering it as a method means it is simple or it is difficult to achieve a superior alternative (Ang et al. 2015).

In AHP method, without the need for access to index data, each index significance can be determined, and there is no need to examine the indexes overlap. According to the above description, AHP method has been used in this research.

The pairwise comparison matrix of the indexes is formed based on the questionnaire that was completed by energy security experts. This questionnaire was completed by eighteen experts in the targeted fields. The expert's dispersion in completing the questionnaire is in accordance with Fig. 6.

As shown in Fig. 6 the experts dispersion in this study is good, so that In terms of experts, the reliability of the resulting pairwise matrix has increased.

Integration of indexes

Integration is the process of merging the weighted indexes and then transforming them into a hybrid index. The most

Table 3 Index coefficients in hybrid Index

Index	Abbreviated name in hybrid Index	Coefficients	inconsistency factor
Energy transfer geography	Geo	0.234	0.03
Economic growth	E.G	0.138	
International support	Int.Sup	0.131	
Neid (net energy import dependency)	Neid	0.091	
WTP (willingness to pay)	WTP	0.088	
Energy consumption	E.C	0.075	
Political consistency	Pol.Con	0.065	
Energy diversification	Div	0.063	
Reserve to consumption ratio	R.C	0.057	
Development of technology	Tech	0.052	

well-known and straightforward integration method is via additive integration where indexes are first multiplied by their weights and then summed to yield the final index. This method is used by 83% of the energy security hybrid indexes that set to integrate their indexes(Ang et al. 2015). Given the above explanation, the present research too employs additive integration for the creation of the hybrid index.

Results and discussion

Questionnaire outcomes were analyzed by the Expert-Choice software to compute absolute index coefficients (given in Table 3) and an inconsistency factor of 0.03. Subsequently, results of AHP method are only reliable for inconsistency coefficients below 0.1 (Poor 2012).

Given the index coefficients of Table 3, the hybrid index for energy security of Caspian region is developed as Eq. (4) and is assigned the acronym CEDSI.

$$\begin{aligned} \text{CEDSI} =& 0.234\ \text{Geo} + 0.138 E.G + 0.131\ \text{Int.Sup} \\ &+ 0.091\ \text{Neid} + 0.088\ \text{WTP} \\ &+ 0.075 E.C + 0.065\ \text{Pol.Con} \\ &+ 0.063\ \text{Div} + 0.057 R.C + 0.052\ \text{Tech}. \end{aligned} \quad (4)$$

Indexes calculation of Iran and Russia swap market

In accordance with Sects. 4.2.4 and 4.2.5, Iran exports gas and oil from swap with Caspian region to three export destinations of China, India and the European Union, as well as Russia's gas and oil received via swap into two export destinations of China and the European Union. According to Table 4, among the ten research indexes, three indexes of international support, political consistency, and geography of energy transfer are specific to the swap market and are not dependent on non-swap markets. But the other seven indexes are dependent on export destinations for swap markets.

The calculation method for independent indexes according to the scenarios is presented in Table 1. However, to calculate export-related indexes, after calculating the model

Table 4 Dependent and independent indexes in swap markets

Index	Swap Market	
	Dependent on export destinations	Independent
Energy diversification	*	
Neid (net energy import dependency)	*	
WTP (willingness to pay)	*	
Energy consumption	*	
Reserve to consumption ratio	*	
Economic growth	*	
Development of technology	*	
Political consistency		*
International support		*
Energy transfer geography		*

Table 5 Coefficients for each swap market destinations

Index	China	India	European union
Energy 2015	0.533	0.365	0.624
Energy 2020	0.500	0.365	0.554
Energy 2030	0.425	0.368	0.507
Oil 2015	0.520	0.365	0.615
Gas 2015	0.469	0.365	0.614
Oil 2020	0.471	0.365	0.531
Gas 2020	0.451	0.365	0.603
Oil 2030	0.375	0.366	0.505
Gas 2030	0.356	0.394	0.567

Table 6 Hybrid index results for gas exports in 2020

Index	Coefficients	China	India	European union	Iran's Swap	Russia's Swap
Energy transfer geography	0.234	0	0.13	0.56	1	0.56
Economic growth	0.138	0.98	1	0	0.594	0.458
International support	0.131	0.5	0.55	1	0	0.83
Neid (net energy import dependency)	0.091	0	1	0.008	0.25	0.004
WTP (willingness to pay)	0.088	1	0	0.25	0.42	0.6
Energy consumption	0.075	0.69	0	1	0.64	0.86
Political consistency	0.065	0.9	0	0.7	1	0.72
Energy diversification	0.063	0.55	1	0	0.44	0.25
Reserve to consumption ratio	0.057	0.43	0	1	0.567	0.75
Development of technology	0.052	1	0	0.65	0.61	0.81
Results		0.51015	0.39447	0.496068	0.580441	0.568058

Table 7 Hybrid index results for oil exports in 2020

Index	Coefficients	China	India	European union	Iran's Swap	Russia's Swap
Energy transfer geography	0.234	0	0.13	0.56	1	0.56
Economic growth	0.138	0.98	0	0	0.594	0.458
International support	0.131	0.5	0.55	1	0	0.83
Neid (net energy import dependency)	0.091	0	1	0.008	0.25	0.004
WTP (willingness to pay)	0.088	1	0	0.093	0.42	0.52
Energy consumption	0.075	1	0	0.283	0.45	0.62
Political consistency	0.065	0.9	0	0.7	1	0.72
Energy diversification	0.063	0.55	1	0	0.44	0.25
Reserve to consumption ratio	0.057	0.489	0	1	0.56	0.76
Development of technology	0.052	1	0	0.65	0.61	0.81
Results		0.536763	0.39447	0.428477	0.565792	0.543588

results in the absence of swap markets, according to the scenario of each swap market, the weighted average of non-swap markets was used. The coefficients for each swap market destinations are given in Table 5. Energy coefficients have been used to calculate indexes such as NEID that cannot be separated into oil and gas.

Results of the hybrid index for Caspian gas exports in 2020

In 2020, Iran and Russia's swap markets both stand in top priority for export of gas from the Caspian region. Results computed by the hybrid index can, therefore, be used as suitable decision making bases for the export of gas to target markets. Markets of China and EU share approximately similar export priorities relative to each other. Iran's swap market surpasses Russia's swap market in 2020. This can be explained by the fact that Iran exports its gas to the three markets of China, India and EU at most and Russia, on the other hand, exports its gas to markets of only China and EU at most. Results obtained by the hybrid index for gas exports from the Caspian region in the year 2020 are given in Table 6. The table numbers are relative and are normalized according to the Min–Max method.

Results of the hybrid index for Caspian oil exports in 2020

Oil and gas markets share the same oil export priorities from the Caspian region in the 2020 year. Swap with Iran presents the best market for Caspian oil exports in 2020. Swap markets of Russia and China have approximately the same priority but Russia still stands in a superior position. Results obtained by the hybrid index for oil exports from the Caspian region in the year 2020 are given in Table 7.

Results of the hybrid index for Caspian gas exports in 2030

Iran and Russia swap markets share the same gas exports priorities from the Caspian region in the 2030 horizon. Next

Table 8 Hybrid index results for gas exports in 2030

Index	Coefficients	China	India	European union	Iran's Swap	Russia's Swap
Energy transfer geography	0.234	0	0.13	0.56	1	0.56
Economic growth	0.138	0.568	1	0	0.45	0.25
International support	0.131	0.5	0.55	1	0	0.83
Neid (net energy import dependency)	0.091	0	1	0.023	0.284	0.013
WTP (willingness to pay)	0.088	1	0.328	0	0.36	0.38
Energy consumption	0.075	0.799	0	1	0.64	0.92
Political consistency	0.065	0.93	0	0.54	1	0.57
Energy diversification	0.063	0.166	1	0	0.33	0.07
Reserve to consumption ratio	0.057	0.048	0	1	0.44	0.63
Development of technology	0.052	1	0	0.587	0.55	0.77
Results		0.417453	0.423334	0.461757	0.541094	0.495303

Table 9 Hybrid index results for oil exports in 2030

Index	Coefficients	China	India	European union	Iran's Swap	Russia's Swap
Energy transfer geography	0.234	0	0.13	0.56	1	0.56
Economic growth	0.138	0.568	1	0	0.45	0.25
International support	0.131	0.5	0.55	1	0	0.83
Neid (net energy import dependency)	0.091	0	1	0.023	0.284	0.013
WTP (willingness to pay)	0.088	1	0.026	0	0.3	0.42
Energy consumption	0.075	1	0	0.169	0.37	0.52
Political consistency	0.065	0.93	0	0.54	1	0.57
Energy diversification	0.063	0.166	1	0	0.33	0.07
Reserve to consumption Ratio	0.057	0.107	0	1	0.44	0.62
Development of technology	0.052	1	0	0.587	0.55	0.77
Results		0.435891	0.396758	0.399432	0.515564	0.468253

priorities are the EU market followed by markets of India and China, respectively. The European share of natural gas in primary energy consumption will rise significantly in 2030 as a result of Europe's environmental policies. India's market too exhibits higher priority relative to China in the year 2030. Upgraded priority of India in 2030 is explained by its high economic growth, high import dependency, increased the tendency to payment in return for energy supply risk prevention and lower energy diversification. Markets of China and India share similar status for the supply of demand security for gas in the Caspian region in this year. The presence of India as one of Iran's swap market export destinations together with Iran's suitable geography suggest a superior status for Iran's swap market compared to the other Caspian markets. Results obtained by the hybrid index for gas exports from the Caspian region in the year 2030 are given in Table 8.

Results of the hybrid index for Caspian oil exports in 2030

Swap markets present superiority for oil exports from the Caspian region in the 2030 horizon. Market priorities are not modified relative to the year 2020 and importantly, priorities of India and EU's markets are approximately equal in this year. In other words, EU market faces a decline in its oil import potential compared to the year 2020 and levels with the Indian market in terms of oil export priorities. Iran's position as a top priority for oil exports from the Caspian region can be explained by its suitable geographical access to oil markets via free waters of the Persian Gulf (index of geography). Results obtained by the hybrid index for oil exports from the Caspian region in the year 2030 are as given in Table 9.

Conclusion

Demand security is an important role player in the development of oil and gas industries in countries or regions. In this work, a hybrid index is developed to explore the capacity of Caspian Markets in providing energy demand security in the Caspian region and its subsequent impact on the exports of oil and gas from the region in years 2020 and 2030. Results produced by the hybrid index for the exports of oil and gas in the years 2020 and 2030 demonstrate the superior state of Iran and Russia's swap markets for providing demand security in the Caspian region when compared to the markets of China, European Union (EU) and India that follow, respectively.

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Appendix 1

The references given in the following table were used to measure variables related to each index. Data for variables given in the below table allow measurements of all indexes except geography and international supports. The SWOT method was used instead to estimate these indexes for which the corresponding values are provided in tables in the conclusion section.

See Table 10.

Table 10 References for each variable and market

Variable	Caspian markets				
	China	India	European union	Iran's Swap	Russia's Swap
Energy consumption	Berkeley Lab, China energy and emissions paths to 2030, 2012	IEA, India Energy Outlook 2040, 2015	Berkeley Lab, China energy and emissions paths to 2030, 2012	_	_
The share of energy carrier in the supply basket (willingness to pay and Neid)	Exxon Mobile Energy Outlook, 2012	Report on Energy Mix in Indian Energy System 2030, NITI Aayog, 2015	Exxon Mobile Energy Outlook, 2012	_	_
The share of energy carrier In the import basket(willingness to pay and Neid)	Northeast Asian Energy Community, Energy Outlook In China For 2030, 2005	IEA, India Energy Outlook 2040,2015	Northeast Asian Energy Community, Energy Outlook In China For 2030, 2005	_	_
Energy intensity (willingness to pay)	Global and Russian energy outlook to 2040, 2014	Global and Russian energy outlook to 2040, 2014	Global and Russian energy outlook to 2040, 2014	_	_
Renewable energy Investment (willingness to pay)	UNEP, global trends in renewable energy investment 2016	UNEP, global trends in renewable energy investment 2016	UNEP, global trends in renewable energy investment 2016	_	_
Economic growth	OECD Economic Outlook 2030, 2012	OECD Economic Outlook 2030, 2012	OECD Economic Outlook 2030, 2012	_	_
Human development index (political consistency)	Boston University, HDI, 2004	Boston University, HDI, 2004	Boston University, HDI, 2004	Boston University, HDI, 2004	Boston University, HDI, 2004
R&D investment(technological development)	The World Bank, Research and development expenditure (% of GDP) data, 2016	The World Bank, Research and development expenditure (% of GDP) data, 2016	The World Bank, Research and development expenditure (% of GDP) data, 2016	_	_

Appendix 2: Analytic Hierarchy Process Questionnaire to determine the weights of indexes

Explain the research

To establish a criterion for examining the Caspian energy markets looking at the Caspian region energy demand security, it is necessary to integrate a series of indexes related to the energy demand security. The type of index can be economic, political, geographic and technological. The first step in indexes aggregation is determining their relative weight. For this purpose, the following questionnaire is set up in accordance with the AHP.

AHP method

In this method, based on a hierarchical analysis, each of the criteria and sub-criteria is compared in binary form, and finally, the importance of each one is determined relative to each other.

How to complete

Each index has the same degree of importance as the other indexes in accordance with the following table. So, according to the table below, consider a number in the comparison of another index.

See Table 11.

Table 11 Criteria

Criteria	Geographical	Economical	Political	Technological
Geographical	1			
Economical		1		
Political			1	
Technological				1

Explanation

For example, if in Table 1, the importance of the geographic criterion is relatively better than the economic benchmark, enter the number 3, in geographical criterion row. In all of the following questionnaires, the completion of the cells above the matrix's main diameter is sufficient. (The lower cells of the main diameter are precisely the opposite of their respective cells at the top of the original diameter. For example, if the significance of the geographic criterion is 3 times the economic criterion, the importance of the economic criterion relative to the geographical one is equal to 1/3).

See Tables 12 and 13.

Explanation

In this questionnaire, the table on the geographic and technological sub-criteria is not mentioned, because each of the geographic and technological criteria has only one sub-criterion.

Table 13 Political indexes

Index	Political consistency	International support
Political consistency	1	
International support		1

Table 12 Economic indexes

Index	Economic growth	Energy diversification	Reserve to consumption ratio	Neid (net energy import dependency)	WTP (willingness to pay)	Energy consumption
Economic growth	1					
Energy diversification		1				
Reserve to consumption ratio			1			
Neid (net energy import dependency)				1		
WTP (willingness to pay)					1	
Energy consumption						1

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