Security of energy supply in Japan: a key strategy and solutions

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Abstract: Energy is essential for goods and services. Japan's economy is dependent on imported energy which is 85% per year, the highest percentage among industrialised nations. The study measures energy supply security (ESS). Four indices; dependency index, intensity index, local production index and composite index are constructed and statistical models are formed out to investigate the significance and the sensitivities between the ESS indexes and the input parameters that are; petroleum prices (PP), gross domestic products (GDP), total primary energy supply (TPES), energy consumption (PCEC), renewable energy (REN), CO_2 emissions (CEM), population (P), traffic volume (TV), human development index (HDI) and mean of democracy indexes of energy suppliers (DI). A comprehensive methodology is used with five statistical procedures including simple correlation analysis, multiple linear regression models, stepwise multiple linear regression model, principal component analysis and cluster analysis. Empirical results indicate that PCEC, P and HDI have significant effect on ESS.

Keywords: Japan; energy supply security; ESS; energy import; principal component; cluster analyses.

Reference to this paper should be made as follows: Erdal, L., Pektaş, A.O., Ozkan, O. and Özkan, F. (2015) 'Security of energy supply in Japan: a key strategy and solutions', *Int. J. Global Warming*, Vol. 7, No. 1, pp.128–159.

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1 Introduction

The use of energy is inevitable for satisfaction of most of the vital services such as heating and lightening in everyday life. However, it brings about some security risks affecting life undesirably in case of unexpected energy cuts and some environmental risks caused by overconsumption of fossil fuels, which may endanger the future of next generations (Erdal, 2011). Similar to the oil crisis which occurred in the 1970's, these days the security of energy supply has again started to draw attention depending on the oil prices which affect the urgency level of the situation (Frondel and Schmidt, 2008).

In this study, security of the energy supply was studied, and factors affecting the security of energy supply were examined both theoretically and empirically. Japan is currently considered to be one of the leading forces or states which are able to adapt to the globalised world and the advanced technology in the world. In this study, energy policy, which is distinctive and security of energy supply which has been meet a large proportion of energy by imports, in Japan were investigated. According to the result of our empirical study, we will give suggestions for the future energy policy of Japan.

For this reason, the security of energy supply was discussed in 4A dimensions namely availability, accessibility, affordability, acceptability. The main determinants of energy supply security (ESS) and with the availability of data, a model is formed out of petroleum prices (PP), total primary energy supply (TPES), per capita energy consumption, carbon dioxide emissions, renewable energy consumption, petroleum import, gross domestic product (GDP), population, total traffic volume, human development index (HDI) and democracy indexes are estimated by simple correlation analysis, multiple linear regression model, stepwise multiple linear regression model, principal component analysis and cluster analysis for the period 1976–2011 for Japan.

This manuscript is organised in the following manner: The definition of energy security and ESS are presented in the next section. The third section briefly represents energy situation and energy policy of Japan. The fourth section designates data description and research framework; the fifth section presents the empirical results and discussion, followed by the conclusion in section six.

2 Energy security

Though security implies different concepts with regard to military, social, economic, political and environmental fields, energy security is a broader definition including all of these variations. However, energy security, as a complex concept, has many meanings, but is most often used in a narrow sense to indicate the stability of a country's energy supply (Wonglimpiyarat, 2009; Von Hippel et al., 2011).

Energy security is commonly defined as the availability of energy at all times in various forms, in sufficient amounts and reliable supply at reasonable prices, without unacceptable or irreversible impact on the economy and the environment. The availability of energy is physical existence of energy sources in a sustainable manner. Reliable and adequate supply point to a rather straightforward meaning: it simply means that energy supply fully meets the needs of the global economy without any disruption. The meaning of affordable energy prices is somewhat less clear as it changes over time and is perceived differently by energy producers and consumers. Energy security definition also includes acceptability of energy sources in terms of environmental concerns (Bielecki, 2002; Bohi and Toman, 1996; Lefèvre, 2007; Chester, 2010; Vivoda, 2012).

Affordable prices of energy sources have different meanings for each country (Müller-Kraenner, 2007). Price fluctuations have adverse impact on economic welfare and on supply-side market power for energy importing countries. Affordable or reasonable prices are insurance against risks of harmful energy import disruptions, which results in a decline of sustainable economic welfare for importers (Bohi and Toman, 1996; Lesbirel, 2004). Import country should improve its own energy security by ensuring a reliable supply of energy at affordable prices in order to support the economy and industry (Dorian et al., 2006). The term energy security refers to the supply of energy sources mainly the oil and natural gas supply without any interruption, affecting the price and the availability of the fuels (Bohi and Toman, 1996; Lefèvre, 2007).

The concept of ESS does not simply mean physical existence of fossil fuel, but, accessibility and transmission of energy in a safe way that is without any trouble during transportation such as security, terrorist attacks and disasters, etc. (Jenny, 2007; Scheepers et al., 2007; IEA, 2004a, 2004b, 2004c, 2007; Chevalier, 2006; Jansen et al., 2004). So the concept of 'ESS' refers to the ability to reach an existing energy source, rather than the depletion of potential sources. This concern is especially valid for non-renewable fossil fuels, which are an unequally distributed energy source and are a critical issue for ESS especially affected by political stability of the supplier country/region.

The new comprehensive energy security concept has five key ingredients – environmental concern, technology improvement, demand-side management or control, social and cultural factors effecting acceptability, and post-Cold War international relations as a result of increased energy trade – are central additions to the traditional supply-side point of view. Security of energy supply is also defined as the uninterrupted transmission of the energy that is safe, reliable and produced from environmentally-friendly resources at a competitive price level to the end user. Establishing security of energy supply is the only prerequisite of sustainable economic growth and development and is ofgreatest importance for policy makers in constructing a successful energy policy framework (Frondel and Schmidt, 2008; Dergiades et al., 2013).

3 Energy situation and energy policy of Japan

By 2030 it is expected that the energy demands of the world, especially in Asia, will immediately rise 1.3 times more than the current amounts. The energy supply structure will be cramped, due to the high competition in acquiring resources among the countries of consumption (APEC, 2012).

Japan now is the third leading economy and the third largest oil consumer[1] in the world just behind China and the USA (WEO, 2012). As the economy of the country has grown, Japan, with an 85% high dependency rate of imported energy supply [oil, natural gas (as LNG), and coal], has been trying to provide its energy needs. Japan, as an examples, can be used to highlight the potential risks of energy import dependency, being the world's largest importer of liquefied natural gas (LNG) and second largest importer of coal and the third-largest net importer of crude oil (Nuttall and Manz, 2008; ANRE, 2011; BP, 2012).

As of 2011, Japan imports approximately 85% of its energy needs, the highest percentage of any major industrialised nation. Main oil and gas suppliers are countries from the Middle East and Southeast Asia. The country is primarily dependent, with roughly 87% dependency rate, on the Middle East for its crude oil imports and factors of energy security such as availability and accessibility of energy sources are vitally important, due to political uncertainty in regions where Japanese crude oil imports originate from; just after the accident in the Fukushima nuclear power plant. Japan has been increasing imports of crude oil for direct burning in power plants to stabilise the electrical power supply. It is currently looking towards Russia, Southeast Asia, and Africa to geographically diversify its oil imports, in order to increase ESS (EIA, 2012; BP, 2012).

Japan has very limited domestic fossil fuels (oil and gas) reserves primarily located along the country's western coastline. However, oil and gas deposits in offshore areas near or on maritime boundaries with other nations (including sea border with China) contain only 1 % reserves which is quite low in energy self-sufficiency. Japan consumes most of its oil in the transportation and industrial sectors. Since Japan relies heavily on imports, it maintains government-controlled oil stocks, to meet its consumption needs and to ensure against an interruption in supply. At the end of December 2011 total strategic oil stocks were 55% being government stocks and 45% commercial stocks (Vanhoorn and Faas, 2009; EIA, 2012).

Although Japan is a minor oil producing country, it has a strong oil sector composed of several state-run, private and foreign companies. In 2006, the government's energy strategy plan encouraged Japanese companies to increase energy exploration and development projects around the world to maintain a stable supply of oil and natural gas. The Japan Bank for International Cooperation supports upstream Japanese oil companies which have sought participation in exploration and production projects overseas. The government has been backing, domestic oil companies due to the country's lack of domestic oil resources and for securing stable energy supply. In 2011, the vast majority of Japan's oil production came in the form of refinery gain, thanks to the country's large petroleum refining sector. In recent years new regulations, on downstream energy sector, has led to an increase in competition among private Japanese firms and foreign companies in the petroleum refining sector. Japan does not have a significant self sufficiency rate of domestic hydrocarbon resources and should develop another solution for energy supply risks. The Japanese government decided to support domestic energy companies who have been actively taking part in upstream overseas oil and natural gas projects and maintaining engineering, construction, financial and project management services for energy projects all over the world where reliable energy supply is possible for economy (EIA, 2012).

National energy security is clearly more evident for countries that do not have abundant resources, like Japan. The policy and regulations instituted by the Japanese government aims to improve energy security in the sense that energy sources could be available, accessible, affordable and acceptable. Nuclear power and nuclear fuel cycle development which have all those characteristics can be important even for energy-rich countries. Because such development will contribute to stability of energy supply (and market stability) and resource conservation by reducing demand for fossil fuels so that the existing capacity can satisfy the energy demand more easily rather than nationalising energy independence and being environmentally friendly (Von Hippel et al., 2011).

The best policy proposal seems to be reducing energy consumption without giving up economic growth, using efficient technology and conserving more. The evolution of Japan's energy conservation policies are seen from a view of energy security to the view of environment protection and low carbon economy. At the beginning of the 21st century, Japan had three goals related to energy policy. Reduction in energy intensity is the first and only prerequisite for fall in energy consumption. Achievement of a more balanced energy mix with lower dependence on oil and lower CO_2 emissions will help to balance the energy distribution more by reducing oil dependence as well as security of energy (Sickles and Spanos, 2000; Ren and Du, 2012). For Japan, nuclear power also can be acceptable as an alternative power source or complementary approaches to reach these goals (Hayashi and Hughes, 2013).

It is a fact that, increased energy conservation and efficiency has been the top priority of Japanese government's policy on ESS. The government generally aims to reduce the share of oil consumed in its primary energy mix as well as the share of oil used in the transportation sector. The share of oil in total primary energy demand, which was 87% in the1970s, fell to about 42% in 2010 as a result of increased energy efficiency and the increased usage of nuclear power and natural gas. Since the oil crisis in the 1970s, Japan has been conducting energetic activities involving both the public and private sectors, resulting in improvements in energy efficiency by about 33% between 1979 to 2009. 1970's Japan has one of the lowest energy intensity rates, among the large developed world economies due to high levels of investment in R&D of energy technology which has substantially increased energy efficiency (IEA, 2012).

It is important to note that efficient use of energy is a key solution for ESS. Countries like China, Japan, Russia, and the USA on the one hand produce 54% of the world's GDP, consume 61% of the world's energy and on the other hand account for 66% of the world's carbon dioxide (CO_2) emissions due to having markedly different energy efficiency and carbon intensity ratios (Aling et al., 2005; Xia, 2012). Fortunately, among them, Japan is four times as energy efficient as China and also, the economy of Japan is six times less carbon intensive as China. The main reason behind the success energy efficiency of Japan, is request of reduction of the severe economic impacts of the oil crisis between 1973 and 1979 and fluctuations in the price of energy that could not be controlled (Vivoda, 2012).

Due to environmental concerns, the Japanese government has encouraged natural gas consumption, consistent with the energy policy aim of acceptability factor of energy sources. The crude oil (42%) and oil products are made up of almost half of primary energy supplies. Coal, natural gas, and nuclear energy sources also have significant shares in primary energy supply of the country. Hydroelectric power and renewable energy sources make up the balance of energy supplies. Now Japan is the world's largest LNG importer, holding about 33% of the global market in 2011 (ANRE, 2011; EIA, 2012; BP, 2012).

The energy security policies in Japan were affected in both short- and long-term by the accident at Fukushima. Several factors that give way to Japan's gas demand, favour the use of LNG over other fossil fuels and consumption of other sources to replace nuclear energy after the 2011 earthquake (Hayashi and Hughes, 2013). Japan has had to replace lost power production capacity of nuclear plants and Tokyo has had no choice but to compensate by additional fossil fuels. Energy – a strategy that give way to increase in Japan's fossil fuel consumption has negatively affected Japan's economy due to rising fuel costs, and has also caused a significant increase in greenhouse gas emissions that deviated from Tokyo's commitment to Kyoto targets. Environmental concerns revealed that promoting renewable energy in generating power increases the share of solar, and other alternative sources and should be supported by a major energy policy review that would contribute to Japan's ESS (Vivoda, 2012).

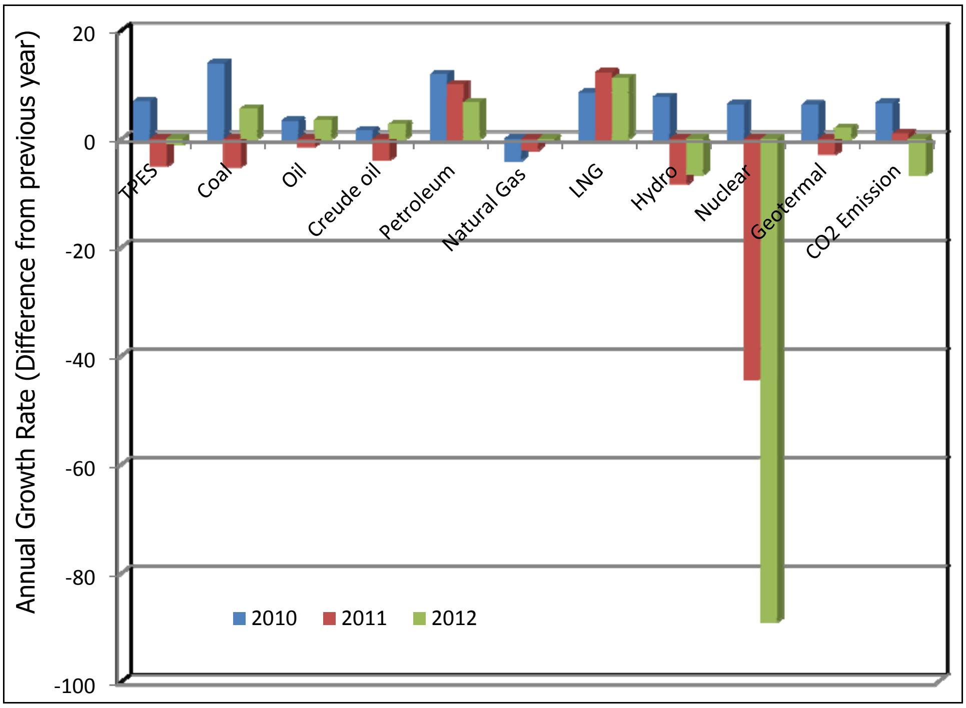
Natural gas use has been supported, as a cleaner and cheaper fossil fuel than oil, by current government carbon-reduction policies aiming to reduce GHG emissions. Destruction of coal-fired electric capacity by the earthquake in 2007, had allowed gas to compete with coal on a cost-basis, (Figure 1) at the end of 2011 (IEA, 2012).

Japan's electricity price has been among the highest of the developed economies. One of the important developments, which began in 1995, is the liberalisation of Japanese electricity markets. Japan has started to implement a liberalisation policy in order to mitigate historically very high retail electricity rates and to enhance the customer service through the introduction of competition while keeping up protection of other public interests such as high quality service, supply reliability, 'energy security' environmental protection and maintaining Japan's industrial competitiveness (EIA, 2012). Japan continues to develop plans and takes measures supported with legal regulations, to enhance energy efficiency across all sectors of the economy.

The process of liberalisation of electricity markets is complicated by the government's promotion of nuclear power, due to the heavy dependency on foreign energy sources or to enhance 'energy security'. Another reason behind nuclear power generation is the stability of supply and the lack of greenhouse gas emissions (EIA, 2012; APEC, 2012).

After the 1980's Japan adopted an ambitious plan to construct substantial new nuclear power capacity, in order to provide a security hedge against a power cut of its oil and natural gas imports as a result of high dependency of oil and natural gas in energy consumption (ANRE, 2011; EIA, 2012; BP, 2012). In 2010, Japan had 64 operating nuclear power plants with a generating capacity of almost 200 billion kWh, increasing nuclear's share of electricity to 41%. In 2011 the earthquake significantly damaged the power generating capacity at four nuclear power stations and refineries, gas and oil-fired power plants, the power infrastructure and the electrical grid used for energy transmission were badly affected by the earthquake. Although some of these facilities were restored, the disruption of energy supplies including electricity, oil and gas, disclosing the sensitivity of Japan's energy system (JWP, 2012).

Figure 1 Annual growth rate of total primary energy supply of Japan (see online version for colours)



Source: The Institute of Energy Economics, Japan (http://eneken.ieej.org.jp/en/jeb/indicators/pdf)

As shown in Figure 1, Japan is substituting[2] the loss of nuclear fuel (growth rate of nuclear power production was –62.9 in 2011) for the power sector with additional natural gas, low-sulphur crude oil, and fuel oil (JWP, 2012; EIA, 2012). The nuclear accident has brought a new perspective on Japan's energy security challenges. While nuclear power only accounted for 13% of Japan's overall primary energy consumption before the accident, Japan relied on nuclear power as a pillar of its central energy security strategy, as a way of achieving an environmentally safe and stable electricity supply, reducing dependency on oil. Following the Fukushima Daiichi Nuclear Power Plant Disaster, Japan's Nuclear Energy Policy is under review. The country plans to fundamentally change its energy supply and demand system by 2030 and aims to increase the electricity supply, by nuclear power, to 50% by 2050 (REEEP, 2012; Vivoda, 2012).

The government's policy has emphasised increased energy conservation and efficiency. The basic point of view in energy policy is energy security, environmental protection, and efficient supply. The strategic energy plan (TSTE) articulates the fundamental direction of energy policy, based on the basic act on energy policy, consistent with the 'new growth strategy' (APEC, 2012). Japan's ambitious targets toward 2030 are;

- doubling the energy self-sufficiency ratio (18% at present) and the self developed fossil fuel supply ratio (26% at present) and as a result, raising its 'energy independence ratio' to about 70% (38% at present)
- raising the zero-emission power source ratio to about 70% (34% at present)
- halving CO_2 emissions from the residential sector
- maintaining and enhancing energy efficiency in the industrial sector at the highest level in the world
- maintaining or obtaining top-class shares of global markets for energy-related products and systems.

After revision, two new points of views were added to the TSTE which are: energy-based economic growth and reform of the energy industrial structure (REEEP, 2012).

Japan has been lowering its dependence on oil through alternative-energy policies in accordance with the *Act on the Promotion of the Development and Introduction of Alternative Energy*[3] which was instituted in response to the oil crisis in 1979. The country aims to raise the share of renewable energy in its energy mix to about 10% by 2020, to alleviate global warming, diversify energy sources, and promote environment-related industries. In January 2013, the government has announced that the largest wind power installation in the world, with 1 GW capacity, would be to build ten miles from the coast of Fukushima and the facility will be in operation by 2020 (REEP, 2012).

The energy market especially for oil and other fuels has become substantially globalised any supply shortage or price rise will affect almost all countries regardless of dependency on foreign suppliers (Von Hippel et al., 2011). Japan now still depends heavily on imported fossil fuels to meet its energy demand and Japan's preferences for future energy paths and policies will have a significant influence on the energy security of the world as a whole and of the Northeast Asian region in particular (Takase and Suzuki, 2011).

4 Research framework and data description

4.1 Model

In this part of the study, econometric techniques were used to investigate the effects of variables on ESS by means of the ad hoc liner model:

$$\begin{aligned} ESS = \alpha_o + \alpha_1 PP + \alpha_2 TPES + \alpha_3 PCEC + \alpha_4 CEM + \alpha_5 REN \\ + \alpha_6 PI + \alpha_6 GDP + \alpha_7 P + \alpha_8 TV + \alpha_9 DI + \alpha_{10} HDI + e_t \end{aligned} \quad (1)$$

where *ESS* is energy supply security indexes, *PP* is petrol price, *TPES* is total primary energy supply, *PCEC* is per capita energy consumptions, *CEM* is carbon dioxide emission, *REN* is renewable energy consumption, *PI* is petroleum import, *GDP* is gross domestic product, P is population, TV is total traffic volume, HDI is human development index, DI is mean of democracy indexes of energy supplier countries of Japan.

4.2 Indicators of ESS

Various definitions are used in the literature for the measurement of the ESS. In this study, three different indicators were calculated for the measurement of ESS. Apart from these, a fourth indicator, which was obtained from the arithmetic mean of the first three indicators, was also calculated.

ESS_1 index measures the 'accessibility' of the energy as the important factor for the security supply of a country is the continuation of the supply regardless of the source of the energy, i.e., domestic or foreign, and getting ready to use it for the country. ESS_2 covers both 'accessibility' and 'affordability' dimensions of the security of supply. Domestic production index (ESS_3) covers the '*accessibility*' dimension of the energy security supply. Presence of energy reserve or the production of energy increases the security supply. By means of composite index, security supply will be evaluated for all dimensions.

4.3 Import dependency

One of the frequently used indicators for ESS is the energy import dependency of which the rate measures the amount of energy to be imported (Kruyt et al., 2009). Import dependency is defined as the ratio of the sum of the net positive imports over all foreign suppliers to the domestic consumption of the respective energy in the country considered. The composition of energy imports is also significant for security. It can be calculated by dividing net energy imports to gross energy consumption plus fuel in international maritime bunkers, expressed as a percentage. If rate is negative, this shows net export of energy. If it is greater than 100 %, this shows the presence of stocked energy. Energy import dependency was calculated as it is given in equation (2) (Erdal, 2011).

$$ESS_1 = \frac{\sum_i TOI_i \cdot TOC_i \cdot TEC_i}{\sum_i TOC_i \cdot TEC_i \cdot GDP_i} \tag{2}$$

ESS_1 energy import dependency ratio

TOI total oil imports

TOC total oil consumption

TEC total energy consumption

GDP gross domestic product.

4.3.1 Energy intensity

Energy intensity is defined as TPES per unit of GDP, measured by tonnes of oil equivalent (toe) per US$1,000 GDP and is considered as a different source of energy in the world due to its potential. Energy intensity defines the energy efficiency and the energy consumption in a country's economy. It is the ratio of energy consumed per GDP (Liao et al., 2007). A common way to measure energy intensity is to look at the ratio of energy production and use to GDP. Energy intensity was calculated as it is given in equation (3) (Erdal, 2011).

$$ESS_2 = \frac{\sum_i IEC_i}{\sum_i GDP_i} \tag{3}$$

ESS_2 energy intensity

IEC industrial energy consumption

GDP gross domestic product.

Decreasing energy intensity would reduce the amount of energy used which entails increasing the industrial competition and a means to enhance 'energy security' by decreasing the amount of imported energy.

4.3.2 Domestic production rate of energy

It shows the share of domestic energy production in the total consumed energy and is considered as an indicator for the ESS. Domestic production rate of energy was calculated as it is given in equation (4) (Erdal, 2011).

$$ESS_3 = \frac{\sum_i DEP_i}{\sum_i TEC_i} \tag{4}$$

ESS_3 domestic production rate of energy

DEP domestic energy production

TEC total energy consumption

In other words, an increase in the share of the domestic sources within the total primary energy consumption is an intended condition for the energy security supply. If the value of this indicator decreases, economic fragility of a country, which may rise because of interruption of energy supply, increases.

4.3.3 Composite index

As an alternative and multidimensional indicator of energy security supply, a composite index, calculated from the arithmetic mean of the first three indicators, was also used. composite index was calculated as it is given in equation (5) (Erdal, 2011).

$$ESS_4 = \pm \sum_i \frac{ESS_1 + ESS_2 + ESS_3}{3} \tag{5}$$

ESS_1 energy import dependency ratio

ESS_2 energy intensity

ESS_3 domestic production rate of energy.

4.3.4 Data and empirical analyses

The dataset was collected from different sources in order to analyse the variables and to propose a new statistical model. The main variables in this research are GDPs, TPES, energy consumption (*kg of oil equivalent per capita*) per capita, share of renewable energy sources (*%*), carbon dioxide emissions (*metric tons per capita*), population, petroleum import, industrial energy consumption (*kg of oil equivalent per capita/%*), domestic energy production, total traffic volume of Japan, HDI and mean of democracy indexes of energy supplier countries of Japan and PP data between 1976 and 2011, extracted from Untied Nations Statistical Data, Annual Energy Review Statistics and British Petroleum.

All mathematical and statistical computations were made by using SPSS 13. Multivariable analysis of the ESS dataset was performed by using correlation, cluster, factor and principal componentanalysistechniques.

5 Empirical result and discussions

5.1 Correlation analysis of ESS

The current study concentrates on analysing the problem of proposing a better formula to investigate the relationships between ESS indexes and input parameters correlated to each other. For this purpose, a well known parametric Pearson correlation and non-parametric Spearman rho correlation analysis are performed to suggest pairwise relations of model parameters and to measure how variables or rank orders are related (Myers and Well, 2003). Pearson correlation test results are given in Table 1 and Spearman's rho correlations test results also are given in Table 2.

Table 1 Pearson correlations

	PI	*GDP*	*PP*	*TPES*	*PCEC*	*CEM*
ESS_1	0.252	–0.463**	0.088	–0.411*	–0.395*	–0.285
ESS_2	*0.547***	*0.955***	0.432**	*0.975***	*0.988***	*0.964***
ESS_3	0.359*	*0.880***	0.274	*0.910***	*0.914***	*0.827***
ESS_4	*0.650***	*0.884***	0.452**	*0.941***	*0.958***	*0.936***

	REN	*P*	*TV*	*HDI*	*DI*
ESS_1	*–0.590***	*–0.697***	*–0.515***	–0.405*	*–0.679***
ESS_2	*0.871***	*0.932***	*0.965***	*0.935***	*0.617***
ESS_3	*0.854***	*0.930***	*0.900***	*0.846***	*0.729***
ESS_4	*0.763***	*0.796***	*0.878***	*0.877***	*0.505***

Notes: **correlation is significant at the 0.01 level (2-tailed).
*correlation is significant at the 0.05 level (2-tailed).

Table 2 Spearman's rho correlations

	PI	*GDP*	*PP*	*TPES*	*PCEC*	*CEM*	*REN*	*P*	*TV*	*HDI*	*DI*
ESS_1	*.67***	–.21	*.53**	–.19	–.15	–.07	–.15	–.20	–.22	–.20	*–.72***
ESS_2	*.53***	*.95***	*.56***	*.96***	*.94***	*.93***	*.92***	*.95***	*.95***	*.94***	*.58***
ESS_3	.241	*.82***	.149	*.83***	*.81***	*.72***	*.78***	*.81***	*.82***	*.82***	*.72***
ESS_4	*.59***	*.86***	.275	*.89***	*.91***	*.89***	*.83***	*.86***	*.85***	*.86***	*.59***

Notes: **correlation is significant at the 0.01 level (2-tailed).
*correlation is significant at the 0.05 level (2-tailed).

The results of ESS_1 in Table 1, which show the energy dependency ratio and the size of oil import in the economy, the significant correlation relations only REN, P, TV and DI variables have values that are over 0.5. As expected from the definition, PI is positively, and the GDP is negatively correlated with ESS_1. Correlation coefficient values of ESS_2 and all other variables are over 0.5, except PP. ESS_3 has high correlations with investigated parameters, only PI and PP has insignificant correlations with ESS_3. ESS_4 is well correlated to all the variables, only PP is insignificant statistically.

The rank correlations that is over 0.5 is indicated in bold in Table 2. The ESS_1 has significant rank correlations with PI, PP DI. While PP and PI has a positive rank correlation, DI has a negative high correlation coefficient as the same with Figure 1. ESS_2 has significant rank correlations to all investigated parameters. ESS_3 is well correlated to all variables except PI and PP. ESS_4 is also well correlated to all the investigated variables except PP.

5.2 Cluster analysis of ESS

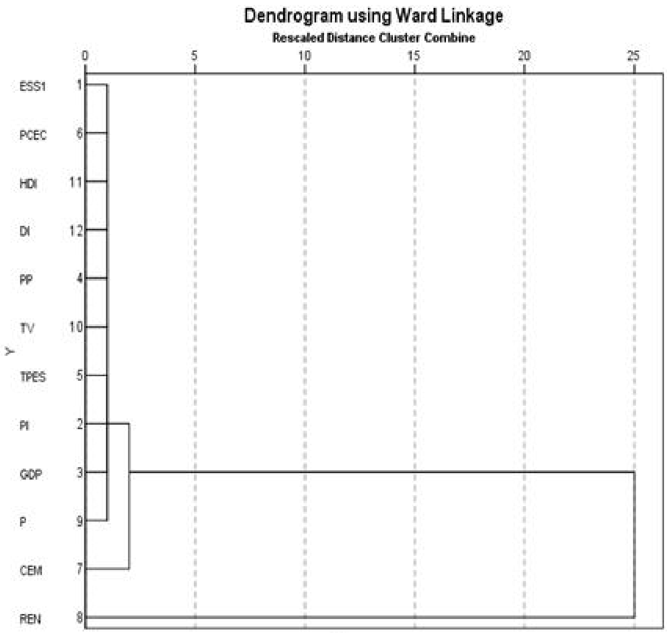
In this study, Hierarchical cluster analysis technique is used. Cluster analysis is performed to reveal the related clusters. Hierarchical cluster models are used instead of cases due to the suitability for clustering by parameters. This method is used to identify the homogeneous groups of variables according to determined properties by means of an algorithm dealing with each variable in different clusters and combining them until one is left (Norušis, 2011).

5.2.1 ESS_1 cluster analysis results

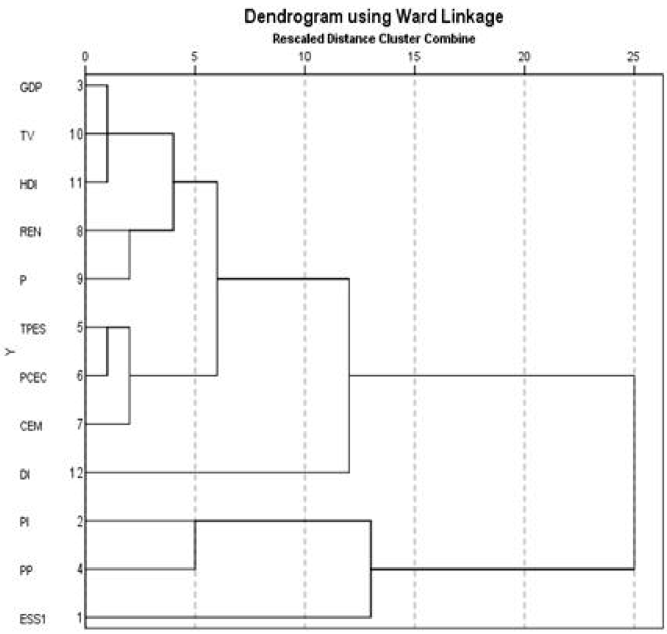
The dendogram which is a graphical summary of the cluster solution is widely used to interpret the results of cluster analysis. For ESS_1 cluster analysis, while Figure 2(a) shows the untransformed dataset dendogram, Figure 2(b) presents standardised dataset results.

Variables are listed along the left vertical axis whereas the horizontal axis shows the distance between clusters when they are joined. This distance is rescaled within the range of 0–25 for a fair comparison between various dendograms. Determining the number of clusters is a subjective process. As a rule of thumb, the longer distance the gaps are searched starting from the right. For example, there is a gap between distance 2 and 25 in Figure 2(a). In Figure 2(a) two main cluster and totally three clusters are suggested. The variables REN and CEM are in distinct clusters from ESS_1. For standardised variables ESS_1 PP and PI is in the same cluster.

Figure 2 Dendograms of ESS_1 and variable clusters



(a)

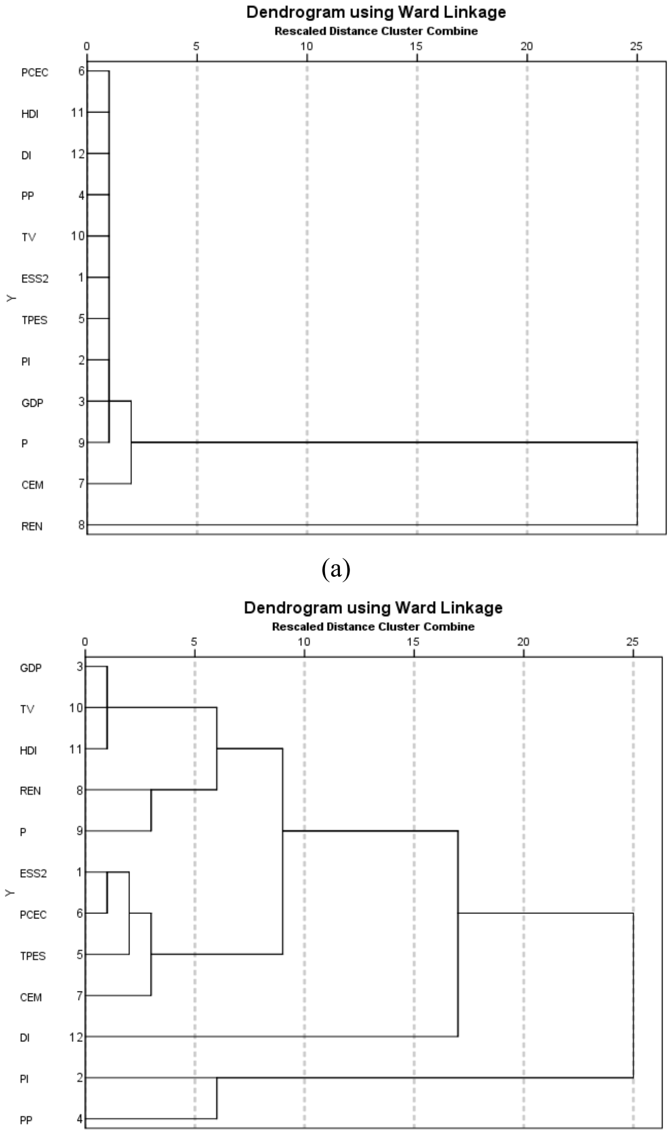


(b)

5.2.2 ESS_2 cluster analysis results

Cluster analyses of ESS_2 are given in Figure 3. Figure 3(a) and Figure 3(b) presents the untransformed dataset dendogram and standardised dataset results respectively.

Figure 3 Dendograms of ESS_2 and variable clusters



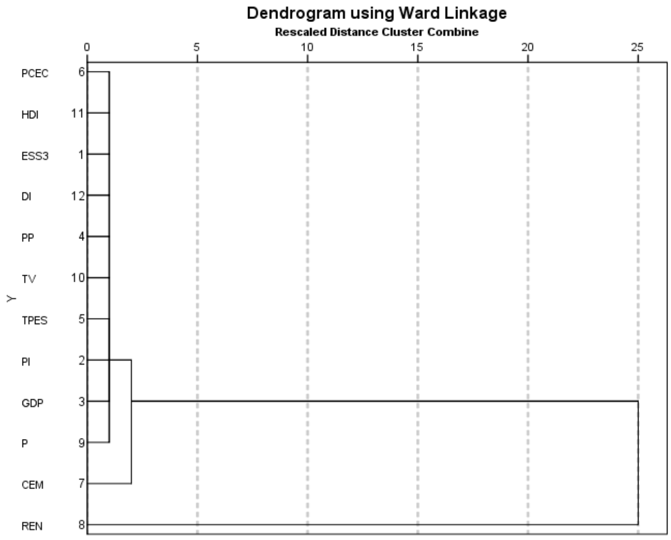
(b)

As seen in Figure 3(a) ESS_2 is in the same cluster with all other variables except CEM and REN. In the second case, for the standardised variables classification ESS_2 is in the same cluster with PCEC, TPES.

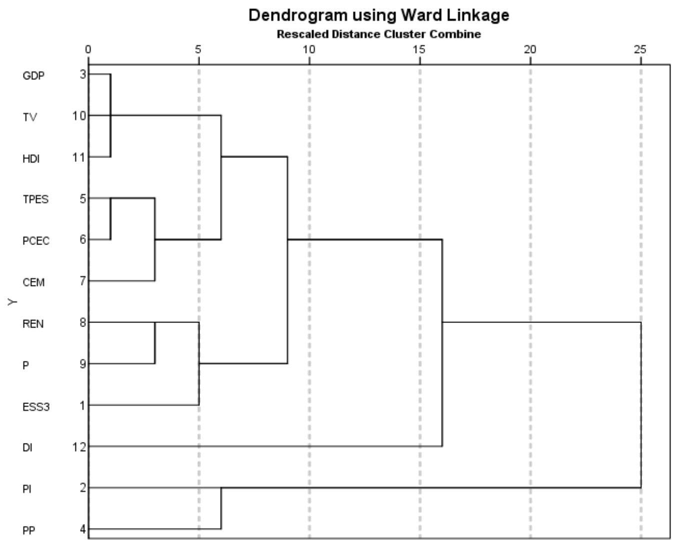
5.2.3 ESS_3 cluster analysis results

Figure 4(a) and Figure 4(b) presents the untransformed dataset dendogram and standardised dataset results of ESS_3 respectively.

Figure 4 Dendograms of ESS_3 and variable clusters



(a)



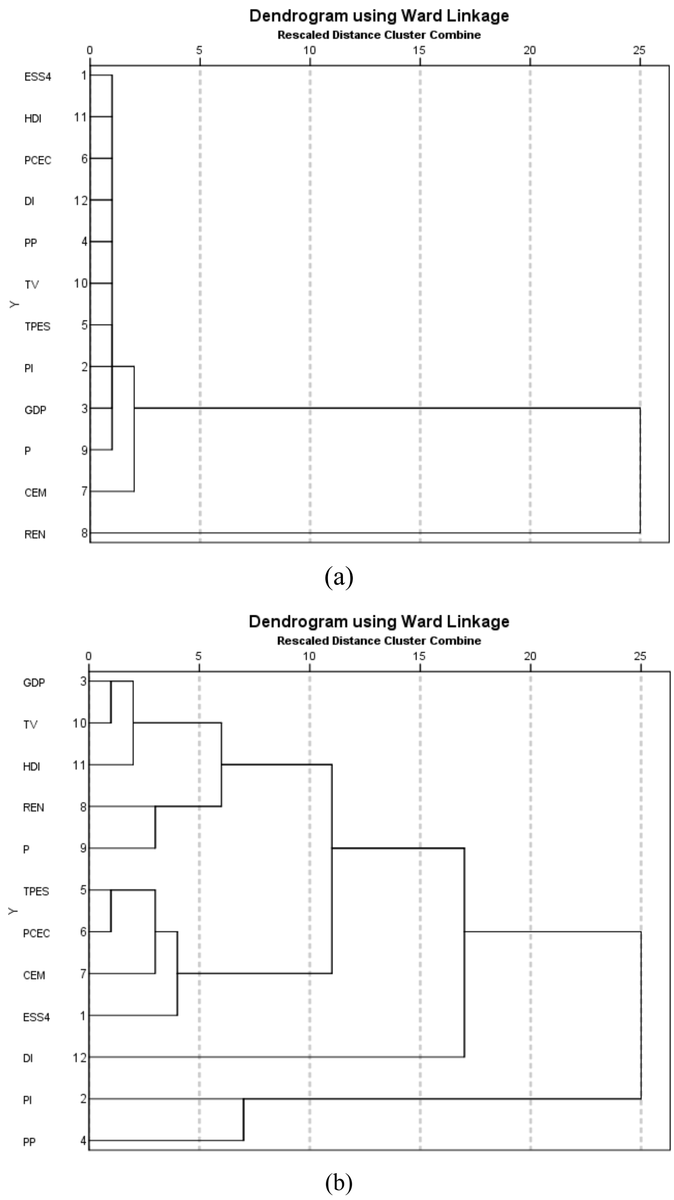
(b)

When the raw variables are used in cluster analysis there is a large cluster which includes many variables. In this case ESS_3 is within this big cluster only CEM and REN are exceptions. For standardised variables analysis ESS_3 is in a second order cluster with REN and P.

5.2.4 ESS_4 cluster analysis results

Untransformed dataset dendogram and standardised dataset results are given in Figure 5(a) and Figure 5(b) respectively.

Figure 5 Dendograms of ESS_4 and variable clusters



ESS_4 is in this big cluster only CEM and REN are exceptions. For standardised variables analysis ESS_4 is in a third order cluster with TYPES, PCEC, and CEM.

5.3 Factor analysis of ESS

Among the various analysis techniques of ESS, factor analysis is one of the most explanatory. The analysis can be used for various purposes to give a new depth of vision to the data processed. For example, it is frequently used to reduce the dimensionality of the original space through forming a new space with a lower number of dimensions than the original one. In fact, new dimensions underlie the old ones (Rietveld and Van Hout 1993). The analysis can also be used to clarify the fluctuations in the observed variables with the help of underlying latent factors (Habing, 2003). For that reason, it allows the output data to be used in further analyses, e.g., to overcome the colinearity problems in regression analysis (Field, 2000).

Factor analysis is based on a correlation matrix giving the intercorrelations between variables. According to Field (2000), the dimensionality of the matrix is reduced by searching for variables that should be highly correlated by a group of variables, but poorly correlated by variables outside of that group. Here 'factor' is defined as a variable with high intercorrelations, which, in fact, measures an underlying variable.

While performing factor analysis, each dependent parameter, ESS in this case, is evaluated by considering all inputs. There are different steps of the factor analysis. The first one is the application of the Kaiser-Meyer-Olkin (KMO) test by which sampling adequacy, i.e., if the partial correlations among different variables are small or not, is determined. Subsequently, the number of factors to be retained is determined. Here, the principles components can be sorted according to their ability to clarify the fluctuation in the original data. On the other hand, frequently, is the selection of components having eigenvalues equal to or greater than one or 80% of total variance (Norušis, 2011).

5.3.1 Principal component analysis of ESS_1

The factor analysis is performed for ESS_1 by including all inputs. In the study, the KMO test, related to sampling adequacy evaluating whether the partial correlations are small or not, was performed. Bartlett's test of sphericity and KMO test results were found to be 0.000, a value lower than 0.05, and over 0.799, respectively. Component 1 and 2 have eigenvalues greater than 1, which meets the first criteria. In addition the components 1 and 2 account for 91.130% of the variance which meet the second criteria. Therefore in the analysis two components are performed.

After component extraction process varimax rotation method is used to extract rotated components. Table 3 shows the component and rotated component matrixes; the results that are presented in tables are suppressed to display absolute values bigger 0.5. As suggested by Field (2000) the value of 0.50 is chosen because the sample is not very big.

As seen in Table 3 the rotated component matrix, two principle components are derived from analysis. The bolded variables can be assumed as the representative parameters of related components. The investigated ESS_1 is in the second component with PI, PP and DI. As a rule of thumb the variables that have more or less a similar influence on both components are excluded (not bolded).

Table 3 Component matrixes, ESS_1 analysis

	Component matrix[a]		*Rotated component matrix*[b]	
	Component		*Component*	
	1	*2*	*1*	*2*
ESS_1		*0.769*		*–0.910*
PI	0.651	0.725	0.940	
GDP	0.998		0.860	0.507
PP	0.581	0.660	0.846	
TPES	0.981		0.837	0.513
PCEC	0.962		0.796	0.540
CEM	0.940		0.841	
REN	0.931		0.735	0.578
P	0.959		0.672	0.726
TV	0.995		0.823	0.559
HDI	0.989		0.889	
DI	0.578	–0.663		*0.870*

Notes: [a]2 components extracted
[b]rotation converged in 3 iterations.

5.3.2 Principal component analysis of ESS_2

The factor analysis is performed for ESS_2 by including all inputs. KMO test is performed and sampling test value is 0.863 and the Bartlett's test indicates the significance of constructed principle component analysis. The total variance that is explained by the components is 93.016%. The component and rotated component matrix results that is presented in Table 4.

Table 4 Component matrixes, ESS_2 analysis

	Component matrix[a]		*Rotated component matrix*[b]	
	Component		*Component*	
	1	*2*	*1*	*2*
ESS_2	*0.971*		*0.941*	
PI	0.673	0.678		0.903
GDP	*0.997*		*0.887*	
PP	0.588	0.715		0.900
TPES	*0.986*		*0.903*	
PCEC	*0.970*		*0.920*	
CEM	*0.954*		*0.859*	
REN	*0.919*		*0.850*	
P	*0.945*		*0.951*	
TV	*0.992*		*0.909*	
HDI	*0.990*		*0.855*	
DI	0.560	–0.718	*0.817*	

Notes: [a]2 components extracted
[b]rotation converged in 3 iterations.

As seen in component and rotated component matrixes the ESS_2 is in the first component with almost all of the variables except PI, PP. The variable DI becomes a significant contributor after rotation.

5.3.3 Principal component analysis of ESS_3

The factor analysis also is performed for ESS_3 by including all inputs. The KMO sampling test value is over 0.5 and the Bartlett's test indicates the significance of constructed principle component analysis. The total variance that is explained by the components is 92.745%. The component and rotated component matrix results are given in Table 5.

Table 5 Component matrixes, ESS_3 analysis

	Component matrix[a]		*Rotated component matrix*[b]	
	Component		*Component*	
	1	*2*	*1*	*2*
ESS_3	*0.907*		*0.961*	
PI	0.658	0.693		0.922
GDP	*0.996*		0.856	0.512
PP	0.575	0.726		0.912
TPES	*0.986*		*0.876*	
PCEC	*0.970*		*0.893*	
CEM	*0.946*		*0.820*	
REN	*0.924*		*0.832*	
P	*0.952*		*0.938*	
TV	*0.993*		*0.881*	
HDI	*0.988*		0.819	0.563
DI	0.576	–0.703	*0.840*	

Notes: [a]2 components extracted
[b]rotation converged in 3 iterations.

As seen in Table 5 ESS_3 is in the first component. PI, PP is not a representative parameter in either component or rotated component matrixes. While HDI is significant parameter only in component matrix, DI is found significant only in rotated matrix.

5.3.4 Principal component analysis of ESS_4

The factor analysis is also performed for ESS_4 by including all inputs in this section. The KMO sampling test value is over 0.5 and the Bartlett's test indicates the significance of constructed principle component analysis. The total variance that is explained by the components is 91.962%. The component and rotated component matrix results are given in Table 6.

Table 6 Component matrixes, ESS_4 analysis

	Component matrix[a]		*Rotated component matrix*[b]	
	Component		*Component*	
	1	*2*	*1*	*2*
ESS_3	*0.921*		1	2
PI	0.689	0.665	*0.843*	
GDP	*0.995*			0.900
PP	0.596	0.703	*0.891*	
TPES	*0.988*			0.893
PCEC	*0.972*		*0.910*	
CEM	*0.956*		*0.926*	
REN	*0.913*		*0.865*	
P	*0.936*		*0.851*	
TV	*0.989*		*0.949*	
HDI	*0.990*		*0.911*	
DI	0.550	–0.732	*0.860*	

Notes: [a]2 components extracted
[b]rotation converged in 3 iterations.

As seen in component and rotated component matrixes the ESS_4 is in the first component with almost all of the variables except PI, PP, DI.

5.4 Linear regression analysis

Linear regression models are developed to investigate the interactions of input parameters within a regression equation to predict the dependent variables (ESS). The main aims are to gain an acceptable level of accuracy and to visualise the stability of regression equations under the impact of correlation between dependent variables.

In backward regression process, first, the variables take part in the equation and then they are removed sequentially. The first variable to be removed is chosen as the one with the smallest partial correlation with the dependent variable. Upon satisfaction of the elimination criterion, the variable is removed. The next variable to be removed is again chosen as the one with the smallest partial criterion among the remaining variables in the equation. When the variables meeting the removal criterion finish, the procedure is ended.

5.4.1 Backward regression model for ESS_1

The dependent ESS_1 (Trans ESS_1) and 8 independent variables except PI and GDP – which are used to derive the ESS_1 – were used to construct the backward model.

The Durbin Watson statistics of the regression residuals is 1.58, additionally the shape of the standardised residual histogram follows the shape of the normal curve fairly well. The R-squared (R^2) value is 0.901 is an indication of the goodness of the fit. The backward regression model consisted of six steps, Table 7 shows the final step model statistics and coefficients.

Table 7 Coefficients and collinearity statistics

Model Step 6	*Unstandardised coefficients*	*Standardised coefficients*	*t*	*Sig.*	*Collinearity statistics*	
	Beta	*Beta*			*Tolerance*	*VIF*
(Constant)	73.926		2.831	0.008		
P	.000	–1.689	–6.468	0.000	0.056	18.005
TV	–.165	–.815	–1.919	*0.064*	0.021	47.642
HDI	169.121	2.293	6.976	0.000	0.035	28.514
DI	–2.968	–.257	–2.770	0.009	0.442	2.264

As seen in Table 7 only DI, P, HDI and TV are included in model at final step. The collinearity statistics indicate that the model is affected by multi-collinearity. While TV is included in the model statistically this parameter is found to be an insignificant contributor for the model to predict the ESS_1.

5.4.2 Backward regression model ESS_2

For the ESS_2 all variables except GDP were included in backward regression model since GDP is a derivative parameter of ESS_2. The dependent variable is Box-Cox transformed ESS_2. The backward model has five steps. The variables TV, PI, TPES and DI are excluded from regression equations along five steps. After the final step the predicted variables are retransformed to the original scales, the R^2 value of observed and retransformed predictions is 0.98. The Durbin Watson statistics of model residuals are 2.243. Table 8 shows the final step model statistics and coefficients.

Table 8 Coefficients and collinearity statistics

Model Step 5	*Unstandardised coefficients*	*Standardised coefficients*	*t*	*Sig.*	*Collinearity statistics*	
	Beta	*Beta*			*Tolerance*	*VIF*
(Constant)	–2.78E+06		–3.272	0.003		
PP	1 425.670	0.086	2.007	*0.054*	0.202	4.955
PCEC	1.15E+07	0.608	4.652	0.000	0.021	46.563
CEM	0.001	0.392	3.361	0.002	0.027	37.121
REN	0.000	0.144	1.929	*0.064*	0.065	15.278
P	0.023	0.250	2.601	0.014	0.040	25.222
HDI	–3.24E+06	–0.414	–2.645	0.013	0.015	66.806

As seen in Table 8 the VIF and tolerance statistics indicates that there is a collinearity problem in the regression equation. The parameter REN is also found to be insignificant by the confidence level of 0.05.

5.4.3 Backward regression Model ESS_3

Box-Cox transformation of ESS_3 is predicted by using all 11 variables as inputs and in the final step (Step 5) only 7 of these variables still remain in the model. The

Durbin-Watson statistics value is 1.804. Table 9 shows the final step model statistics and coefficients.

Table 9 Coefficients and collinearity statistics

Model Step 5	*Unstandardised coefficients*	*Standardised coefficients*	*t*	*Sig.*	*Collinearity statistics*	
	Beta	*Beta*			*Tolerance*	*VIF*
(Constant)	–54.111		–3.242	0.003		
GDP	0.000	–2.129	–3.926	0.001	0.004	228.409
PP	0.043	0.431	3.314	0.003	0.076	13.127
PCEC	299.689	2.664	8.555	0.000	0.013	75.275
CEM	0.000	–1.040	–5.073	0.000	0.031	32.642
REN	0.000	0.630	3.504	0.002	0.040	25.119
P	0.000	0.471	1.917	*0.065*	0.021	46.910
DI	1.723	0.236	3.404	0.002	0.268	3.730

As seen in Table 9, the coefficients and collinearity statistics of the regression equation is ill from multicollinearity. Standardised coefficients indicate that GDP and PCEC have the most influential parameters of the model. P is an insignificant contributor for the model (0.065 > 0.05).

5.4.4 Backward regression model ESS_4

Backward regression model was applied to predict ESS_4 by using the 11 correlated variables. At the final step of the analysis (Step 5) while the parameters PI, PCEC, CEM, REN, P are found to be significant, predictors of ESS_4 the GDP and DI are found to be relatively insignificant by the significance level of 0.05. The prediction accuracy of model when compared with observed values ESS_4 is 0.97. Residuals Durbin-Watson statistics is 1.616 and the ANOVA test for the model is confirming the models significance (Table 10).

Table 10 Coefficients and collinearity statistics

Model Step 5	*Unstandardised coefficients*	*Standardised coefficients*	*t*	*Sig.*	*Collinearity statistics*	
	Beta	*Beta*			*Tolerance*	*VIF*
(Constant)	0.849		0.918	0.366		
GDP	0.000	0.267	3.083	0.005	0.146	6.833
PP	0.000	–0.531	–1.941	*0.062*	0.015	68.256
PCEC	14.967	1.998	8.687	0.000	0.021	48.267
CEM	0.000	–0.572	–3.011	0.005	0.030	32.894
REN	0.000	0.389	2.752	0.010	0.055	18.198
P	0.000	–0.588	–2.563	0.016	0.021	48.020
DI	0.056	0.116	1.876	*0.071*	0.287	3.484

5.5 Evaluation of the statistical techniques and hierarchical regression models

5.5.1 Evaluation of ESS_1

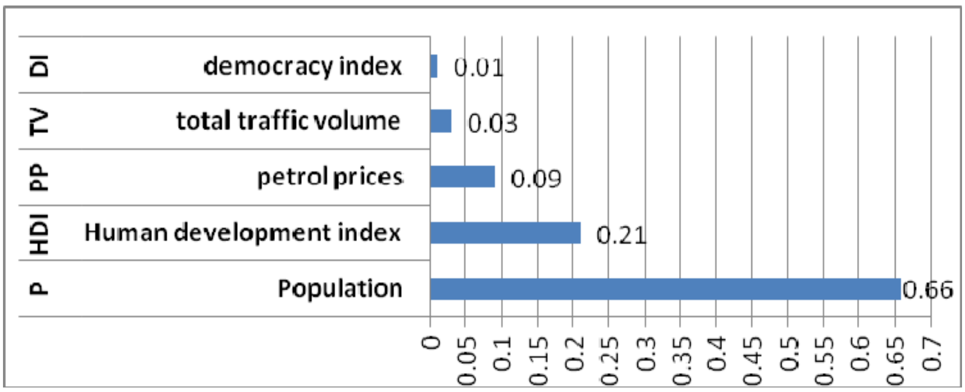
The results of all statistical procedures applied for ESS_1 are shown in Table 11.

Table 11 Statistical procedures evaluation, ESS_1

Variables	*Simple correlation analysis*	*Non parametric correlation*	*Principal component analysis*	*Cluster analysis*	*Backward regression*	*Number of ticks*
PI		√		√ x		3
GDP				√		1
PP		√		√ x		3
TPES				√		1
PCEC				√		1
CEM						0
REN	√					1
P	√			√	√	3
TV	√			√		2
HDI	√			√	√	3
DI	√	√	x	√	√	5

It is obvious that the *DI* is the most influential parameter for predicting ESS_1, while the parameters PI, PP, P and HDI are found to be relevant parameters to ESS_1, CEM and REN are found to be irrelevant parameters. Therefore a hierarchical linear regression model comparison is used including DI, P, PP, and HDI to predict ESS_1. Thus the PI is used to derive ESS_1 it is not included in the models. The Akaike information criteria (AIC) is used to compare the models. AIC is widely used in model comparison and lowest values indicate the accuracy success of model. Another criterion of model selection is the principle of parsimounity. If the inclusion of an item does not contribute significantly then that model is rejected even if it has the lowest AIC value.

Figure 6 Variable importance analysis (see online version for colours)



Despite model 4 having the lowest AIC value, model 3 is chosen to develop a parsimonious and accurate model. As shown in Figure 6 the parameter DI is an insignificant contributor, and the usage of this parameter does not reduce the AIC significantly. The Durbin Watson residual statistics of this model is 1.7, ANOVA test confirms that model is appropriate, R^2 and adjusted R^2 values are 0.938, 0.932 respectively. The regression equation of model 3 is;

$$ESS_1 = 0.972 + 0.00004P + 0.958HDI + 0.00003PP \quad (6)$$

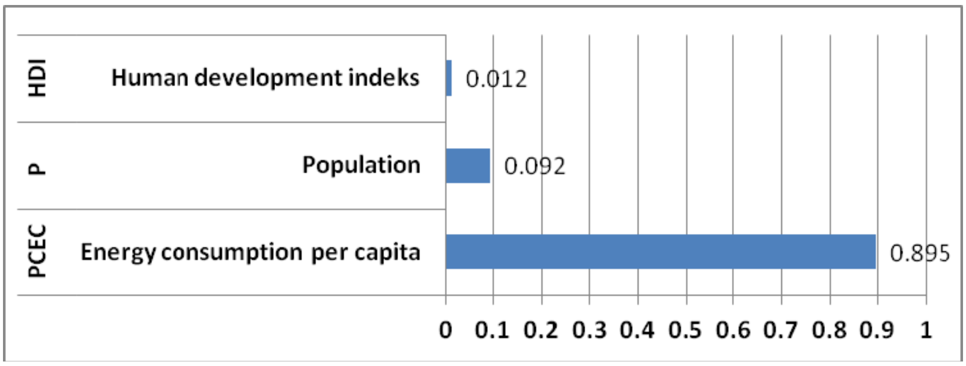
5.5.2 Evaluation of ESS_2

Final judgment of relation of ESS_2 is presented in Table 12.

Table 12 Statistical procedures evaluation, ESS_2

Variables	*Simple correlation analysis*	*Non parametric correlation*	*Principal component analysis*	*Cluster analysis*	*Backward regression*	*Number of ticks*
PI	√	√		√		3
GDP	√	√	√ x	√		5
PP		√		√		2
TPES	√	√	√ x	√		5
PCEC	√	√	√ x	√ x	√	7
CEM	√	√	√ x		√	5
REN	√	√	√ x			4
P	√	√	√ x	√	√	6
TV	√	√	√ x	√		5
HDI	√	√	√ x	√	√	6
DI	√	√	x	√		4

Figure 7 Variable importance analysis (see online version for colours)



GDP is excluded in evaluation process since it is a derivative parameter for ESS_2. The PCEC is found to be the most relevant parameter; also HDI and P can be suggested for the hierarchical regression models. These three parameters are used in hierarchical regression analysis.

Inclusion of HDI decreases the AIC by a very small level and the importance of HDI is insignificant (Figure 7) so model 2 is selected by parsimonuity principle. The regression equation of final model for ESS_2 is;

$$ESS_2 = -332.966 + 2.21E + 0.3PCEC + 2.7410^{-6} P \tag{7}$$

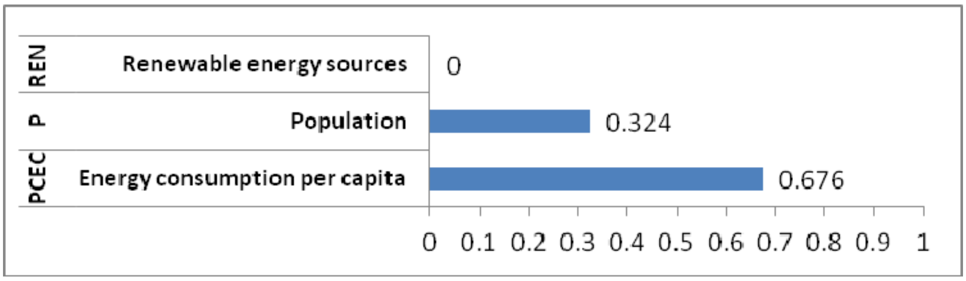
5.5.3 Evaluation of ESS_3

The results of all statistical procedures applied for ESS_2 are shown in Table 13.

Table 13 Statistical procedures evaluation, ESS_3

Variables	*Simple correlation analysis*	*Non parametric correlation*	*Principal component analysis*	*Cluster analysis*	*Backward regression*	
PI				√		1
GDP	√	√	√	√	√	5
PP				√	√	2
TPES	√	√	√ x	√		5
PCEC	√	√	√ x	√	√	6
CEM	√	√	√ x		√	5
REN	√	√	√ x	x	√	6
P	√	√	√ x	√ x		6
TV	√	√	√ x	√		5
HDI	√	√	√	√		4
DI	√	√	√	√	√	5

Figure 8 Variable importance analysis (see online version for colours)



The evaluation chart (Table 13) shows that the most related variables with ESS_3 are PCEC, P and REN. Therefore, hierarchical models are developed by using these variables.

For the perspective of model selection criteria, the best model includes only PCEC and P as predictors and the AIC value is –91.057. The regression equation of ESS_3 is;

$$ESS_3 = -33.236 + 57.299 PCEC + 2.4410^{-7} P \quad (8)$$

The variable importance graph is presented in Figure 8, the PCEC is almost twice as important as P to predict ESS_3.

5.5.4 Evaluation of ESS_4

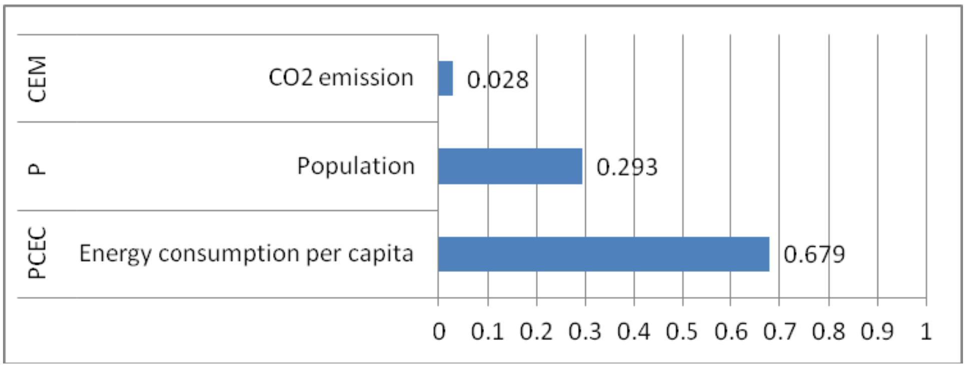
Final judgment of relation of ESS_4 is presented in Table 14.

Table 14 Statistical procedures evaluation, ESS_3

Variables	*Simple correlation analysis*	*Non parametric correlation*	*Principal component analysis*	*Cluster analysis*	*Backward regression*	*Number of ticks*
PI	√	√		√	√	4
GDP	√	√	√ x	√		5
PP				√		1
TPES	√	√	√ x	√ x		6
PCEC	√	√	√ x	√ x	√	7
CEM	√	√	√ x	x	√	6
REN	√	√	√ x		√	5
P	√	√	√ x	√	√	6
TV	√	√	√ x	√		5
HDI	√	√	√ x	√		5
DI	√	√	x	√		4

As seen in evaluation table (Table 14) inside all investigated variables the most relevant one is PCEC, second-order significant variables are TPES, CEM and P. Since TPES is highly correlated to other three variables, it is not included in models because of colinearity effect. Therefore, a hierarchical regression approach is conducted by using three variables.

Figure 9 Variable importance analysis (see online version for colours)



While the lowest AIC is in model 3, the significance of the third parameter of this model is not sufficient (Figure 9) and also the AIC decreased amount is very low. So model 2 is a parsimoniousideal model to predict ESS_4. This model R^2 and adjusted R^2 values are 0.946 and 0.942, respectively. The regression equation is;

$$ESS_4 = 1.317 + 9.513PEC - 1.4010^{-8}P \quad (9)$$

5.6 Discussion

In the determination of ESS_1 which represents the accessibility dimension in the ESS, energy dependency ratio was examined. In the identification of the energy dependency of Japan, the third largest crude oil importer in the world after China and, USA, petroleum dependency ratio was used. After performing five different statistical analyses, PI, PP, P and HDI were identified as the parameters explaining ESS_1 and this was tested by hierarchical model. Population seems to be the most influencing parameter for the crude oil dependency of Japan. This could be related to the fact that Japan is the third largest oil importer in the world. It is remarkable that HDI is the second effective variable. The mean value of the HDI of Iran, Qatar, UAE, Russia and Saudi Arabia i.e., the countries from which Japan import petroleum was used. Security of energy supply is directly related to the HDI index of the countries from which Japan import oil. The index representing the living standards of these countries is a measure including the average life expectancy, literacy ratio, the level of education and life standards. Meanwhile, the price of crude oil is directly related to the HDI index of the petroleum exporting countries. An increase in the domestic consumption of the oil in the petroleum exporting countries decreases the amount of oil exported by these countries and thus oil prices increase. Even if the oil consumption of petroleum importing countries decreases, the share in the budget that they considered for the petroleum does not change or increase. Due to the fact that Japan's security of energy supply is vulnerable, the government should pay attention to the challenges of energy security. Japan should differentiate energy sources by renewable (wind, solar) domestic energy sources and also should differentiate energy supplier country/region from which it imports petroleum in a wider spectrum and include countries/regions in its portfolio with various HDI values so as to eliminate these risks.

Interrelated results were obtained by the data obtained from the five different statistical analyses of ESS_2 that represents availability, affordability and acceptability dimensions of the supply security. In the results of HDI, P and PCEC, which were included in the hierarchical regression model, energy consumption per capita seemed to be the variable that influenced the ESS_2 to the highest extent. ESS_2, which represents the energy intensity, is mainly defined by the amount of the GDP obtained by the unit energy consumption and is considered as a different source of energy in the world due to its potential. The decrease in the energy density would reduce the energy consumption, an important production input, increase the industrial competition and, increase the ESS by decreasing the import of energy. Another noticeable index that was included in the hierarchical regression model was HDI, as it was in ESS_1. It can be apparently seen from ESS_1 and ESS_2 that the development of the countries from which Japan import petroleum has a significant effect.

In the five different statistical analysis performed by ESS_3, which represents the availability dimension of the ESS, results related to most of the data being obtained. In the results of the hierarchical regression models, it was observed that PCEC and P are influential on ESS_3. ESS_4, which was obtained by the arithmetic mean of ESS_1, ESS_2 and ESS_3, it involves all dimensions of the ESS and it was examined at the last stage. The results of the hierarchical regression model, in which CEM, P and PCEC were used as input, energy consumption per capita was determined as a variable affecting ESS_4 to the highest extent.

When models involving the statistical relations between ESS indexes, which were measured by different dimensions, and independent variable factors, it can be seen that the ESS was influenced positively from the primary energy supply and renewable energy ratio while it was influenced negatively from energy consumption per capita and CO_2 emission.

Although independent variables changed, the stability of their sign and significance level showed the models were robust. Oil prices were estimated as negative, while it was found to be statistically reliable for all models where dependency indexes were used.

Countries should reduce their energy consumptions in order to prevent from welfare transfer and economic recession due to high energy prices. The measures proposed to reduce factors threatening security of energy supply, which could be diversification of the energy mix, increased energy efficiency, increased renewable energy rate as an alternative source, increases potential of domestic energy supply (Balat, 2010). In order to promote energy security, countries should invest in advanced technologies that reduce the energy intensity, increase efficiency and decrease import dependency. The reduced energy intensity or efficient use of the energy would reduce the energy consumption and production costs. Meanwhile, it would also increase the ESS by decreasing the consumption of fossil fuel and greenhouse gas emission. Renewable energy sources and nuclear energy, as an alternative energy source to the fossil fuels, mitigate the Climate Change. Additionally, it reduces the import dependency as a result in increase of the domestic consumption of the energy (Erdal, 2011; Felgenhauer and De Bruin, 2012).

According to World Economic Forum, today and in the future, population and GDP are two of the most important determinants in the energy consumption of developing countries (Sohn, 2008). The levels of economic and social development, financial and cooperative conditions, local, regional and global environmental concerns, energy supply and intensity, new and developed technologies, accessibility to the modern energy sources become prominent components influencing ESS (Kruyt et al., 2009). Countries with a high import dependency, energy efficiency is an effective solution ensuring energy security and environmental protection as it aims to decrease overall primary energy consumption, increase energy savings and will directly decrease import dependency. Another clear contribution of energy efficiency to security of supply is environmental protection due to the decline in fossil fuel consumption as well as CO_2 emission.

Japan's energy demand would increase by population, the size of economy and energy consumption per capita. Short-term or long-term disruptions in energy supply would increase the economic vulnerability and negatively affect security energy supply. Some energy security risks at the end of the 20th century, such as major oil shocks in the 1970's and 1980's and the Gulf War in 1990, clearly demonstrate the vulnerability of Japan's economy (Von Der Mehden, 2000; Bilgin, 2010).

6 Conclusions

Energy security refers to the association between uninterrupted availability of energy supply and national security. Energy is vital for transportation, communication, security, health delivery systems etc. Due to the fact that energy powers the economy and the army of countries, access to energy with reasonable prices, is very important not only maintaining economic welfare but also national security as well. For Japan, that is poor with fossil energy resources and relies heavily on imports to meet its consumption needs, energy security is a particularly important challenge.

Energy security risks like the competition for energy resources, manipulation on energy supply resulting price volatility, high import dependency, political instability in energy exporting countries/regions, accidents, natural disasters, attacks on supply infrastructure, in-state conflict, exporters' interests are some of the factors affecting supply and transportation of energy sources. Risk factors can arise from political or economic problems and may adversely affect the energy industry in the supplier country as well.

In Japan, high dependency on oil has been an important security risk threatening economy due to the possible oil disruptions in the last three decades. To enhance energy security, the government reorganised the energy sector, diversified the energy sources, made some diplomatic efforts with the oil exporting countries, promoted the domestic fuel sources and made investment in energy infrastructure and nuclear power production, increased the energy taxes, built national stockpiles and purchased oil fields abroad. Since the precautions are very costly, today there is still a debate whether to continue with these measures or not.

The security of energy supply is considerably important for Japan, which imports 85% of its energy needs and is the third largest crude oil consumer in the world. Under the current circumstances, the energy policy of Japan seems to be correct, thanks to the correct timing of the decisions made. However, it is an unquestionable truth that the security of the energy supply is always at risk.

The investment of Japan to the nuclear power plants, started in the1980'sto reduce the foreign dependency which played a crucial role in this success. Natural disasters, such as the Fukishima earthquake, which occurred in recent years, made the nuclear power plants highly questionable and as a result of this, contribution of these plants to the overall energy production is decreasing day by day.

It is recommended that in order to be well prepared, and to reduce the risk of ESS or to be able to react appropriately against future disruptions, Japan should pay attention to the following points related to their energy policy:

- Japan meets its own crude oil need mostly from Gulf countries in the Middle East. As these countries have not been democratised yet, and stability of these regimes depends on many factors which poses a great risk. Thus, broadening of the portfolio of the country to fulfil the petroleum demand and making cooperation with North Asia countries on energy is inevitable for energy producers.
- Japan should pursue a policy of supply diversification both in energy supplier countries and regions via alternative suppliers and alternative routes.
- It is necessary to establish friendly relations with energy rich, or main supplier countries, and countries on transportation routes, which could be used to bring energy to the market.
- Diversification of primary energy mix and diversification of electricity production are regarded as the main solutions to energy insecurity.

- Japan should review the nuclear energy policy, enhance nuclear power technologies which are more environmentally friendly.
- Eliminate the monopoly power of OPEC.
- In order to decrease import dependency, investments in renewable energy sources and new advanced technology should be increased.
- Policies should be developed to improve energy efficiency through continued efforts for energy conservation by both public and private sectors, and houses and buildings.
- The safety requirements for the nuclear power plants, which have been taken care of since the nuclear accident, should be increased and developed appropriately for emergency response procedures for any risk scenarios.

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Notes

1 India's energy consumption is almost equal to Japan and will become third energy consumer.

2 The implementation of Basic Energy Plan (Strategic Energy Plan) based on the experience of the Great East Japan Earthquake and the accident at TEPCO's Fukushima Daiichi Nuclear Power Station.

3 The Alternative Energy Law; The Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities has taken effect on 1 July 2012.