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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

ENERGY SUPPLY SECURITY INDEX: AN ANALYSIS FOR TURKISH ECONOMY

ENERJİ ARZ GÜVENLİĞİ ENDEKSİ: TÜRKİYE EKONOMİSİ İÇİN BİR ANALİZ

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ABSTRACT

Energy consumption in Turkish economy has been rising continuously and composition of energy mix will be substantially changed in forthcoming periods due to environmental concerns and economic sustainability. On the other hand, energy shortage expected to increase because of accelerating economic activities and increase in population. In addition, structure of energy markets and demand/supply balance in Turkey are closely related with financial stability (current account deficit). Therefore, there is need to balance between energy consumption-economic growth and environment duality in energy policy. Conversely, any disruptions in energy supply will lead to destabilize economy, interruption in output and suspend social life in the long term. Accordingly, rising and ennsuring energy security would be helpful for Turkish economy. In this frame we assesed energy security in line with Cabalu (2010) on the basis of energy intensity, import dependency, domestic production and geopolitical risk indicators. Lastly, we derived a composite security index from them. Results showed that Turkey is vulnerable in terms of fossil fuels due to insufficient domestic production and huge share in the national energy mix. On that note, policy makers can target possible sources of supply disruptions and mitigate their effects by taking measures against risks in energy security.

Keywords: Energy Security Index, Energy Mix, Energy Policy.

JEL Classification Codes: O13, P28, P48

ÖZ

Türkiye ekonomisinde enerji tüketimi sürekli artmaya devam etmekte ve enerji karmasının, çevresel endişeler ve sürdürülebilir büyüme yüzünden önemli derecede değişmesi beklenmektedir. Diğer yandan artan ekonomik faaliyetler ve nüfus artışı ekonominin enerji açığını artırmaktadır. Ayrıca Türkiye'deki enerji piyasalarının yapısının ve arz/talep dengesizliklerinin finansal istikrar ve ekonomik sürdürülebilirlik ile olan yakın ilişkisi unutulmamalıdır. Bu yüzden büyüme ve çevre ikilemindeki denge mutlaka sağlanmalıdır. Aksine enerji arzında yaşanabilecek problemler uzun vadede, ekonomide istikrarsızlık yaratacak, toplam çıktıda kesintiler ve günlük hayatta aksamalar görülebilecektir. Bu yüzden Türkiye ekonomisi için enerji güvenliğini sağlamak ve artırmak faydalı olacaktır. Bu çerçevede enerji güvenliği Cabalu (2010) çalışmasındakine uygun şekilde değerlendirilmiş ve enerji arz güvenliği için enerji yoğunluğu, ithal bağımlılığı, yerli üretim ve jeopolitik risk göstergeleri kullanılmıştır. Son olarak bu dört gösterge bağlamında Türkiye ekonomisi için kompozit risk endeks hesaplanmıştır. Sonuçlara göre fosil tabanlı yakıtların enerji karması içindeki yüksek payı ve yetersiz yerli üretim kırılganlığı artırmaktadır. Bu bağlamda karar vericiler bu doğrultuda enerji güvenliğini artıcı önlemler alarak arz kesintileri karşısında doğabilecek olumsuz sonuçları hafifletebilirler.

Anahtar Kelimeler: Enerji Güvenliği Endeksi, Enerji Karması, Enerji Politikası.

JEL Sınıflandırma Kodları: O13, P28, P48.

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GENİŞLETİLMİŞ ÖZET

Amaç ve Kapsam:

Bu çalışmanın amacı Türkiye ekonomisi için enerji arz güvenliği (enerjinin hane halkları ve firmalara kesintisiz, uygun kalite ve fiyatta, çevre hassasiyetleri de dikkate alınarak arz edilmesi) risk endeksi oluşturmak ve zamana göre Türkiye'nin geldiği noktayı ve içinde olduğu eğilimleri yorumlamaktır. Türkiye genç ve dinamik yurt içi pazarı, hızlı büyüyen ekonomisi ile dünyada enerji tüketiminin hızlı arttığı önemli pazarlardan biridir. Ancak Türkiye coğrafi konumu, jeolojik yapısı, gerekli sektörel alt yapı yatırımlarını yetersiz yapmış olması nedeni ile enerjide kendi kendine yeten ülkelerden değildir. Bu da ülkenin enerji güvenliği ile ilgili hızlı tüketim artışı, fosil tabanlı yakıtlara ola yüksek bağımlılığı, buna bağlı kendi kendine yeterlilik oranının düşük olması, enerji ithalatı faturasının ekonomi üzerinde oluşturduğu ağır yük ve yol açtığı cari açık ve son olarak enerji yoğunluğunun hala istenilen seviyelere inmemiş olması gibi sorunları beraberinde getirmiştir.

Yöntem:

Enerji güvenliği risk endeksleri ile ölçülür. Bu sayede ülke geldiği noktayı, diğer ülkelerle kıyaslamayı ve ne gibi tedbirler alması gerektiğini öğrenebilir. Bu amaçla pek çok risk endeksi geliştirilmiştir. Ancak bu endekslerin ortak bir tanımı yoktur. Risk göstergeleri ülkeden ülkeye, enerji karmasına ve kaynaklarına göre ve kaynak donanımına göre değişmektedir. Bu yüzden değerlendirmeler daha kapsayıcı olması için farklı risk göstergeleri üzerinden yapılır. İşte bu amaçla basit ve bileşik olmak üzere iki farklı sınıfta risk endeksleri oluşturulmaktadır. Literatürde enerji arz güvenliğini değerlendiren basit risk endeksleri yaygın olarak kullanılmaktadır. Ancak bileşik endeksler enerji arz güvenliğinin farklı boyutlarını daha iyi kavramakta, boyutun enerji sistemi içindeki önemine göre farklı ülkeler için farklı ağırlıklar kullanma imkânı vermekte ve ülkeler arası karşılaştırma yapılabilmektedir. Bileşik göstergeler, enerjinin elde edilebilirliği, alt yapı, fiyat, sosyal etkiler, kamusal yönetim, verimlilik üzerinden ölçülerek ekonomik, politik, fiziksel, sosyal ve çevresel riskler değerlendirilir. Enerji yoğunluğu, kaynak tahmini, rezerv tüketim oranı, kaynak çeşitlendirme, ithalat bağımlılığı, enerji fiyatları, politik istikrar, yeşil enerjinin tüketim içindeki payı, piyasanın likiditesi, ve biyo-yakıt kullanım oranı gibi göstergeler basit endekslerde kullanılırken, arz/talep endeksi, kırılganlık endeksi, yoğunluk endeksi, Shannon-Wiener endeksi, Lerner endeksi, Herfindhal-Hirschman endeksi ve Uluslararası Enerji Ajansının geliştirdiği arz güvenliği endeksi bileşik endekslere örnek olarak gösterilebilir. Bu çalışmada literatürde kullanılan bileşik (composit) endeksleme yöntemleri ile Türkiye ekonomisinin enerji arz güvenliğinin sağlanmasında yukarıda belirtilen problemlerin nicel analizinin yapılması ve sonuçlarının yorumlanması hedeflenmiştir. Çalışmada Türkiye ekonomisinde petrol, doğal gaz, kömür ve yenilenebilir enerji kaynakları için risk endeksi 1980-2018 dönemini kapsayacak şekilde oluşturulmuştur. Kullanılan göstergeler Dünya Bankası Veri Tabanı, EPDK enerji dengesi tabloları ve TUİK veri tabanından milyon ton eş değer petrol birimi bazında alınan politik istikrar endeksi, yıllık enerji tüketimi, yerli üretim ve enerji ithalatı verileridir. Reel milli gelir ise zincirlenmiş hacim endeksine göre alınmıştır. Bu sayede risk endeksi zaman serisi verileri çerçevesinde analiz edilerek uzun vadeli eğilimler belirlenebilmiş ayrıca enerji karmasındaki tüm kaynaklar kapsama alınmıştır.

Bulgular:

Bulgular kısmında ilk olarak enerji yoğunluğu için sonuçlar verilmiştir. Doğal gaz ve kömürde risk göstergeleri 2000'li yılların sonuna kadar artarken 2010'dan itibaren yenilenebilir enerjiye verilen teşviklerin artması ve enerji karmasının içindeki payının artmasına bağlı olarak yumuşama yaşanmıştır. Petrol ise tüketimde sürekli düşüş eğiliminde olduğu için yoğunluk risk göstergesi düşük seviyelerdedir. İthalat bağımlılığında ise aynı şekilde Türkiye'nin dinamik ekonomisi, tempolu ekonomik büyümesi, hızlı nüfus artışı ve artan şehirleşme gibi nedenlerle artan enerji ihtiyacının kısa vadede enerji ithalatı ile çözmeye çalışması neticesinde doğal gaz ve kömür için risk göstergeleri yüksektir. Petrolde ise belirtildiği gibi 1979 krizinden beri tüketim payında sürekli düşüş eğiliminde olduğu için risk göstergesi Türkiye için önemli bir kırılganlığa işaret etmemektedir. Benzer şekilde kendi kendine yeterliliğe dayalı üçüncü gösterge tüm enerji tiplerinde yüksek kırılganlığa işaret etmektedir çünkü Türkiye ekonomisinin yerli enerji üretimi kaynak yetersizliği ve yatırımsızlık nedeniyle yetersizdir. Yenilenebilir enerji 'nin payı artsa da doğa koşullarında bağlı oldukları için üretim açığını karşılamakta yetersiz kalmaktadır. Dördüncü gösterge jeopolitik riskleri temsil eden çeşitlendirme endeksine göre petrolde 2008 krizine kadar azalan risk ve sonrasında artan risk görülmektedir. Kömürde ise yeterli çeşitlendirme yapılamadığı için kırılganlık tüm dönem boyunca artmıştır. Doğal gazda ise negatif şoklara karşı kırılganlık, Rusya'ya karşı Azerbaycan gazının daha fazla ikame edilmesi ve spot piyasalara dönüşle birlikte ılımlı bir rahatlama görülmektedir.

Sonuç ve Tartışma:

Türkiye'nin kömür ve gazda negatif şoklara karşı kırılganlığını azaltılması bağlamında alması gereken önemli mesafeler vardır. Özellikle kaynak ülke ve enerji tipini çeşitlendirme, enerji yoğunluğunu azaltma, sektördeki rekabeti artırma, verimliliği artırma, arama-tarama faaliyetlerini artırma, tüm enerji sektörü yatırımlarına daha çok teşvik verme, enerji koridoru ve enerji hub olabilme rolünü pekiştirme akla gelen en önemli politika önerileridir. Bu sayede oluşturabilen sürdürülebilir enerji sistemleri ve rekabetçi piyasa yapısı, Türkiye'nin büyüme ve kalkınma temposunu en iyi şekilde destekleyecektir.

1. INTRODUCTION

Energy has been basic elements of modern economies, human societies and our way of daily life since industrial revolution. Functioning of modern economies is impossible without modern energy systems. Modern industrial process, transport activities, health services, agriculture and all socio-economic activities requires energy. But nowadays, access to modern energy services afflicts over a third of the world's population and limits economic opportunities and widens the gap between rich and poor countries. Energy is a crucial for poverty alleviation and ameliorate living standards. Thus lack of energy is related with general poverty. Also energy is an input for nearly all goods and services. Economic growth and energy are linked strongly. It means as economies grow, it will consume more energy (Sharma and Tryggestad, 2012; Barnes Khankder and Samad, 2010: 2-4; WEF, 2012).

In this sense need for reliable and affordable energy is more fundamental for either developing or developed nations. Reliable, uninterrupted, affordable and environment friendly energy systems support expanded industry, modern agriculture systems, promote international trade and improved transportation sector. But today most of the consumed energy comes from fossil fuels (e.g. oil, gas, coal) and their consumption rate is too much higher than their million years of formation rate. It means they are finite resources. Besides they can also irreversibly damage the environment due to Green House Gases (GHGs) emissions from fossil fuels.

Secondly global energy demand is expected to rise totally about 25% toward 2040 due to increasing demands from developing countries. Therefore energy security will continue to be an important issue in energy policy agendas and macroeconomic policies. The major challenge for policymakers is to implement rational energy strategies for ensuring security based on a careful consideration of their costs and benefits and the possible interactions between domestic policies (Labenderia and Manzano, 2012: 7-9; Faas, Gracceva, Fulli and Mesera, 2008: 10-11; Cherp and Jewel, 2014: 415-417).

In the literature substantial number of empirical studies mainly focused on energy security. Also there are many numbers of index that generally focused on fossil fuels (especially crude oil) and mostly on industrialized countries. But from all of these studies, time series data to directly assess trends in energy security are rarely seen in the literature. In this study we modeled the multiple dimensions of energy security concept by computing composite index and we conduct supply security index method enable us to measures risk score by different energy source and time period. For dynamic Turkish economy, need for economic growth, rapid population rate, import dependence on foreign energy resources have made energy security concept an important research objective. Hence we focused on energy supply security of Turkish economy and evaluate their trends from past to present on the basis of different energy types. So our paper is important by providing security metrics to assess overall energy supply security in Turkish economy and for future policy making to assess weakness in energy supply.

2. ENERGY SECURITY

2.1. Definitions of Energy Security

Energy security concept had gained importance during World War I with supplying oil for war machines. For many years it has cited on concern about stable energy supply, the regional concentration of resources and the results of the strategic withholding of energy. This perspective consider that energy is essential for industrial production, agriculture, consumption and daily life. Over years, the meaning of concept has changed and gained insight after major supply disruptions of the 1970s oil crises and even the early 1990's. (Yergin, 1991: 410; Brown, Rewey and Gagliano, 2003: 7-8). Academic interest on subject goes back to the 1960s and get highest point with 1970s oil crises. But after decreasing negative effect of oil crises, the academic interest declined again in the pursuit of the stabilization of oil prices. Security studies had reawaked in the 2000's due to rising economic growth in Asia, disruptions of gas supplies in Europe (Russian-Ukrainian conflict) and the pressure to de-carbonize energy systems. In its historical development process, energy security concept has evolved stable supply of affordable oil under economic embargoes and price manipulations in financial markets to beyond oil supply and involve wider range of issues such as providing energy increasingly in adequate quantity and quality, affordable cost and environmentally sound to satisfy economic needs (Yergin, 2006: 70-74; Hughes and Lipscy, 2013: 452-453; Cherp and Jewel; 2014: 417).

Numerous definitions of energy security can be found in the literature and there is no common interpretation due to complication and definition of the concept (Chester, 2010). One definition is made by European Commission in 2000 green paper stated as "the uninterrupted availability of energy resources or fuels on the market, at a price that is affordable for end user while respecting environmental concerns and paying attention toward sustainability" (European Commission, 2000). Another definition is the ability of end customer and producers to adjust disruptions of supply in energy markets (Stocking and Constantio, 2012). The Department of Energy and Climate Change of U.S.A. defines as the risks of interruption to energy supply are low (Department of Energy & Climate Change, 2009). According to Christian Winzer energy security means the risks of interruption to energy supply are low" (Winzer, 2011: 4-6).

We can also define it according to time period because time scale affects risk types in energy security. In this case short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance. It means availability of energy supply even if there is exceptional demand and supply conditions, due to extreme weather conditions, terrorist attacks, accidents or other physical (stop production) or economic factors (e.g. extreme price fluctuation or speculative movements in energy markets). Also risk types which have seen in the short term is different from the long term. In the long term energy security is deal with ensuring forthcoming demand can be met by both imported and domestic supplies (Cabalu 2010: 1; IEA 2020). All of these definitions handle the subject from their perspective. In other words definitions of energy security varies with regard to one's position in the value chain. It is different for developed and developing countries, energy importing or exporting nations. It is also different for long or short term periods or different in national and regional policy perspectives (Barton, 2004: 8).

2.2. Dimensions of Energy Security

In the light of broad definition of energy security, basic dimensions of this concept could be characterized by the position and benefit of participants. Accordingly many studies (e.g. Asian Pacific Energy Centre) assess the concept on four topics; availability, accessibility, affordability and acceptability (APERC, 2007: 7-32: Ang, Choong and Ng, 2015: 1081-1083).

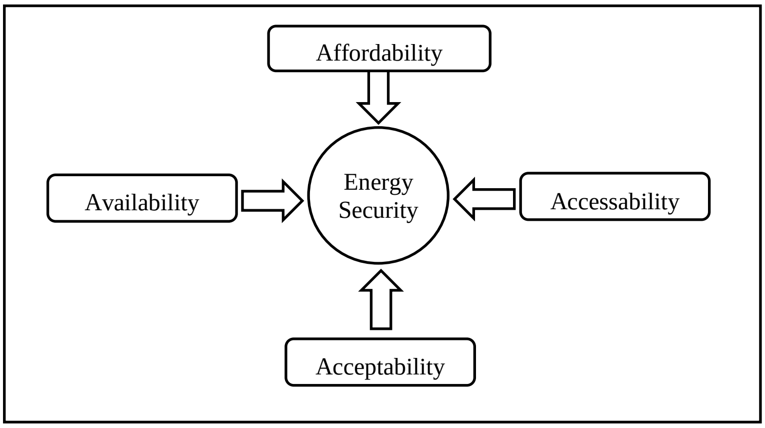

Figure 1. Dimensions of Energy Security

Source: (Chelly, 2011: 3).

Availability of resources can be defined as the functional relationship between the cumulative extraction of resources at a point of time and determining variables. In this context availability of energy means existence of energy sources that makes energy supply in sufficient and uninterrupted way especially by taking into consideration swiftly depleted fossil fuels (Nordhaus, 1979: 35-37). The second element of energy security is accessibility which means on the one hand expression of geopolitical distance between production & consumption of energy and their location of physical resources, on the other hand supplying energy continuously to consumers (Elkind, 2010: 119).

The third component of energy security is affordability. From the perspective of producers, it express clearly proved reserve of energy resources to be profitable enough to bear capital and extraction cost (Erdal, 2012: 11-12). On the other hand affordability for consumers means supplying energy at reasonable prices and also protecting them from price fluctuations (Sovacool and Brown, 2009: 10).

The last component of energy security is acceptability which draw attention to environmental stewardship. Continuity in energy supply and environmental conscience is crucial for sustainability. Prevailing method of energy extraction, production and transportation has been leading to environmental pollution and upset the balance of ecosystem (Below, 2013: 860-861). Also fossil fuels that meet 85% of world energy demand are decomposing rapidly. So energy production and consumption has to be in the manner that balancing current resource consumption with the resource requirements of next generation, decreased energy related environmental impact, curbed pollution from the energy industry. Within this scope energy resources which any economy is going for are being described sustainable (Sovacool and Brown, 2009: 11).

2.3. Importance of Energy Security

Each economy has to ensure its energy security because of needs for economic growth and social concerns. Most economic activities in the world are conventionally based on fossil fuels (oil, coal and natural gas), and only sufficient and uninterrupted supply can guarantee future energy security (Haluzan, 2013). Vice versa energy insecurity may cause political risk (using energy deliveries as political weapon by energy exporting countries), economical risk (macroeconomic equilibrium may affect negatively by volatility in energy prices), physical risk (disruption in supply as a result of stoppages in energy production, exhaustion of energy resources or natural disasters), social risk (conflicts in society that are linked to continuous increases in energy prices) and environmental risk (nuclear accident, oil spills etc.) (Kocaslan, 2014: 738).

Importance of energy has expanded considerably after the industrial revolution which based industrial production upon machines instead of man-power. The laws of thermodynamics require that energy is necessary for the material transformations that are related to most production processes. Besides energy is both used as intermediate inputs in production process, transportation and also important as final product that is necessary for basic human life. (Labanderia and Manzaro, 2012: 2). In exactly the same way, importance of energy security derives its critical role from the fact that energy plays in all aspects of daily life and business life. We can summarize importance of energy security under three items;

a) Economic disruption,
b) Public health and safety,
c) *Environmental effects*.

Firstly high-tech economies in today's world require stable petroleum and electricity-based energy system to meet their needs. Any interruptions in the manufacturing, distribution and marketing of petroleum-based fuels could affect the persistence of the transportation system. Secondly disruption in energy supply would not only interrupt power transmission, but also would affect public health. Interruption of energy supply as a result of terrorist attack, explosion or industrial accident in energy infrastructure (e.g. nuclear power plant, dam, refineries) would affect public health by events such as toxic clouds, radiation or massive fires. And also Interruptions in energy supply to hospitals or other public infrastructure such as water or sewer systems could undermine function of the lighting, refrigeration, and monitoring, pumping and other related systems. Lastly energy disruption affect the quality of environment in the wake of oil spill in maritime tanker operations or offshore oil platform operations and breaking out a natural disaster that damage power plants (Brown et al., 2003: 8-12). So it should be implemented by both developed and underdeveloped economies with the concentrate upon providing modern energy services to all consumers in safely way. Also it should apply to the entire supply chain, it should comprise all predictable time-horizons and it should allow for the improving new technologies in a sustainable, economic and environmentally-sound manner (El-Badri, 2008).

2.4. Challenges for Turkish Energy Security

It is generally assumed that global competition for energy resources will redefine the mutual interaction between economics and politics in coming decades. Therefore, energy security is one of the top priorities for many countries around the world. Each country is looking for ways of ensuring secure, clean and affordable energy to their end user (Hisarcıklıoğlu, 2014: 28). But lack of modern energy systems, underinvestment in energy markets, outdated technologies and unsustainable use of indigenous energy sources (traditional biomass) put more pressure on energy supply in developing and underdeveloped countries than those of developed countries. Especially energy importing countries like Turkey are faced with insecure, inadequate, barely affordable and unstable energy supplies that undermine their economic development (Ölz, Sims and Kirchner, 2007: 14-15).

Turkey is a developing country with 82 million population (right scale) and nearly $771 billion gdp (left scale) and its energy markets have been expanding sharply in line with economic growth. Nevertheless there have been predominantly one fundamental approaches in Turkish energy policy that meeting energy demand under any circumstances. Under this condition, state led oriented, inefficient and foreign dependent energy sector has come into existence. The only rationale behind energy policies of Turkish economy is to realize beneficial outcomes of positive relationship between energy and economic growth. To satisfy growth demand, energy policy has widely focused on supply side instead of energy efficiency precautions or resources diversification (Can, 2006: 1-2; Celebes, 2006: 17-20).

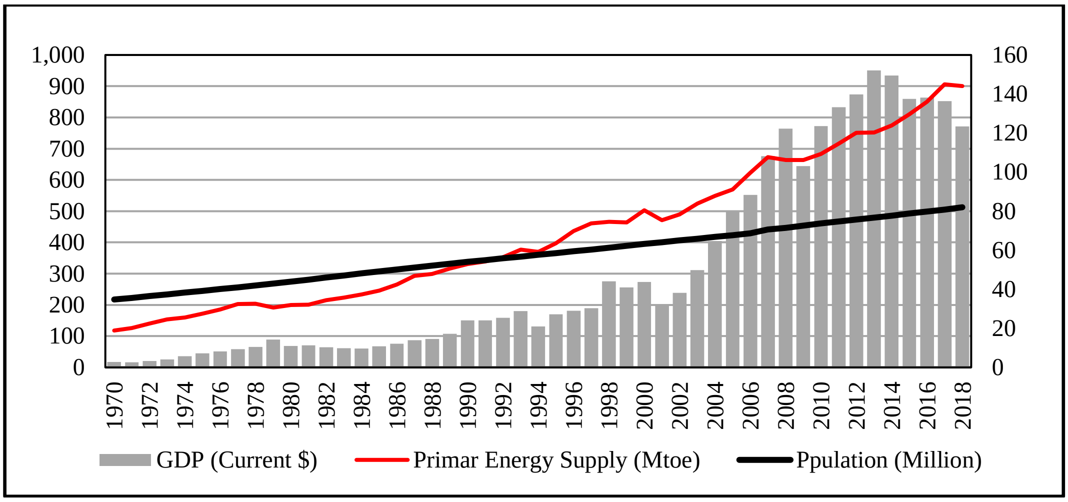

Figure 2. GDP, Population and Energy Consumption in Turkish Economy

Source: (Ministry of Energy and Natural Resources, 2020; TUİK, 2020).

Firstly high rate of energy consumption has put pressure on energy supply to increase more it should be. Rapid urbanization, dynamic population and economic growth, rising expectations of consumers and technological progress along with inadequacies in energy efficiency programs and underinvestment in energy markets has resulted in high rate of energy consumption. According to BP statistical review (2018), while world energy consumption has increased 2,4% averagely from 1970 to 2018, the same number was 4,5% for Turkish economy and projections to 2030 expected that it will be 1,6% for world average and 4% for Turkey.

Secondly heavy use of fossil fuels are another risk for Turkish economy. Energy consumption in the world has been rising rapidly and this consumption bases mainly on fossil fuels. Heavy use of fossil fuels compounded by resource depletion, climate changes, global warming and eventually exhaustion of global oil and gas resources potentially increase vulnerability in supply disruption of energy importing economies in the World.

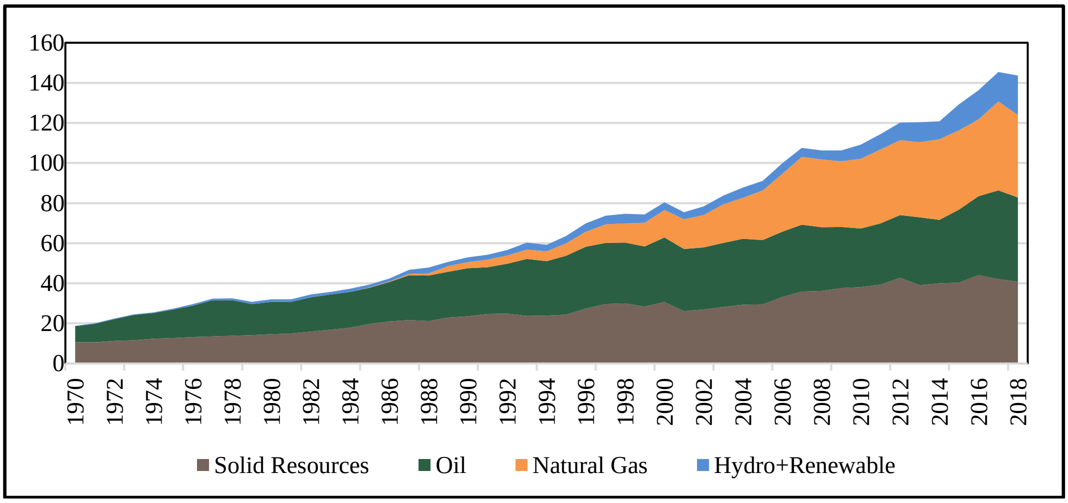

Figure 3. Primary Energy Supply in Turkish Economy by Resources (Mtoe)

Source: (Ministry of Energy and Natural Resources, 2020).

Also geopolitical developments such as wars, terrorism, pandemics and financial crisis complicated the situation and more expose countries to risk sources (Turton and Barreto, 2006: 2232). As can be seen from figure 3, Turkish economy is mainly rest on fossil fuels which account for 84% of primary energy supply and Turkey is poor in terms of oil and natural gas reserves. Domestic natural gas and oil production capacity covers only 2% and 11% of its yearly consumption respectively. So this unbalanced situation is the main challenge for Turkish energy supply security.

Thirdly self-sufficiency (figure 4) in energy consumption in other words ''import dependence'' is deal with availability dimensions of energy security which measured by percentage of total primary energy supply divided by total primary energy consumption (Sovacool, 2013: 151). Availability is the vital element of energy security and in this sense, high import dependence rate increase the risk of supply disruption because of insufficient availability of alternative domestic sources in the face of foreign sources (Löschel, Moslener, Rubbelke, 2010: 1667). It's hard to manage and exploit foreign energy sources both technically, economically and politically. In this respect Turkish economy is in a poor condition that self-sufficiency in total primary energy consumption is hardly reached 15%. So Turkey has to be developed alternative sources and also share of domestic sources should be increased in total consumption to avoid destructive outcomes of supply shocks.

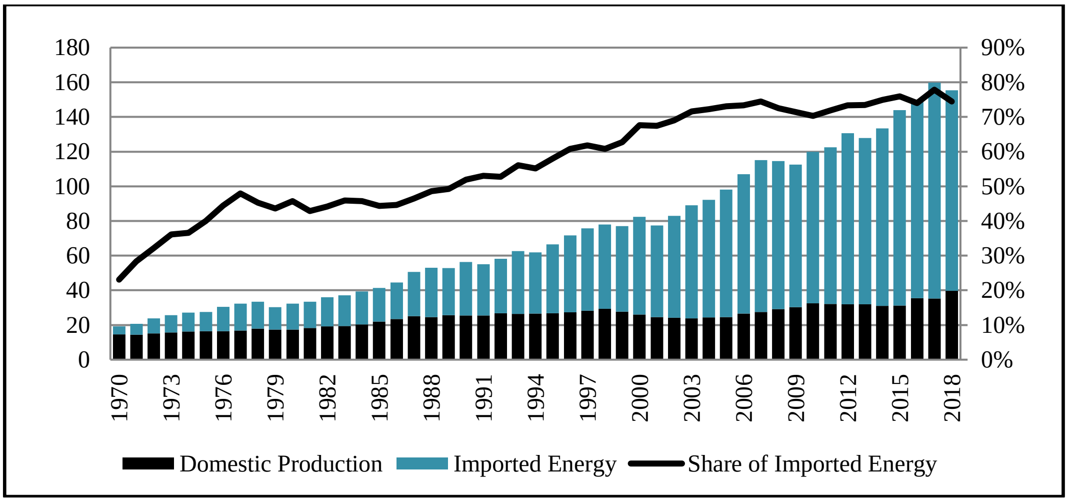

Figure 4. Self-Sufficiency Rate in Primary Energy Supply (Mtoe, %)

Source: (Ministry of Energy and Natural Resources, 2020).

Heavy cost burden in total import is also problem both for energy supply security and macroeconomic stability of Turkish economy. One of the main macroeconomic imbalances of Turkey is current account deficit which is about 10% of GDP in 2011, 6,1% in 2012 and 7,1% in 2013 and 3.6% in 2018.

Indeed low level of domestic saving rates assert itself in current account deficit and makes Turkey highly dependent on foreign savings (it means current account deficit) in order to be able to realize economic growth. The import coverage ratio of export which is the measure of exports power or inflow of foreign currency is not sufficient to meet the needs of raw material and intermediate goods of Turkish industry. This creates an important macroeconomic deadlock for the economy in terms of creating a trade-off between economic growth and current account deficit. It means the more exports goods and services, the more it has to import. So this is the vicious cycle of Turkish foreign trade. Also price fluctuations (e.g. oil and gas price) in international energy markets is another risk. Higher price means higher energy import and prices will cause increase Turkey`s current account deficit and therefore, higher financing needs. (Aslan, 2016: 3-5, Karagöl, Kavas, Kaya, and Özdemir, 2017: 10-13; MFA, 2019).

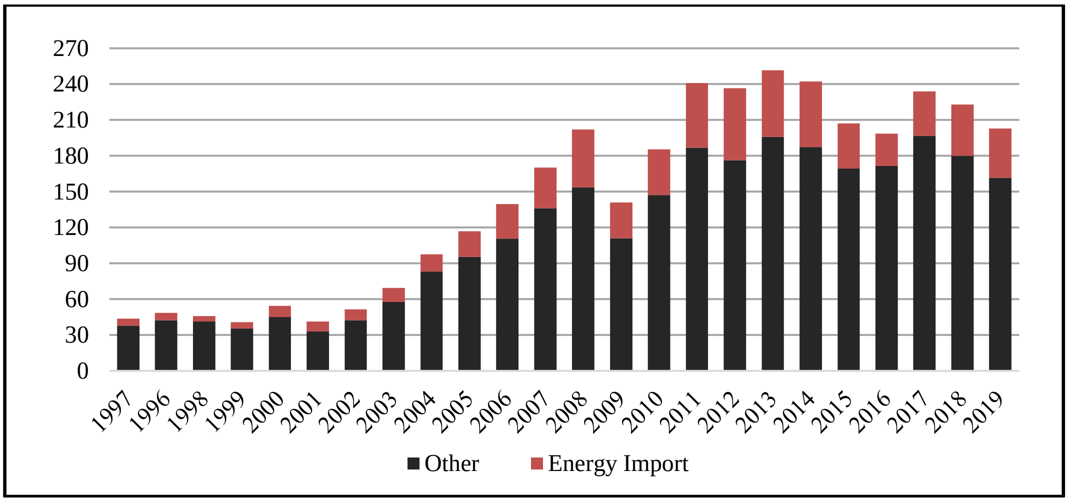

Figure 5. Energy Import of Turkish Economy (Billion $)

Source: (Ministry of Energy and Natural Resources, 2020).

As shown in figure 5 Turkey has imported energy and energy products to cover huge demand roughly $60 billion in 2012 and $55, 9 billion in 2013 and $41 billion in 2019. According to one approaches for estimating the impact of energy prices on external balances concluded that a 10 percent decline in energy prices leads to a 0.39 percentage point improvement in the current account balance to GDP ratio of Turkish economy. Nearly one fifth (22,8%) of total import is only consist of energy import as of 2019.

When we look at figure 6, it's obvious under these numbers, current account deficit mainly has come from energy imports. As Turkish economy has grown, energy import has raised together and costed heavily to Turkish economy year by year. If we could exclude energy items for total import, current account deficit would be close to positive surplus nearly (Demirtaş, 2013: 8-9).

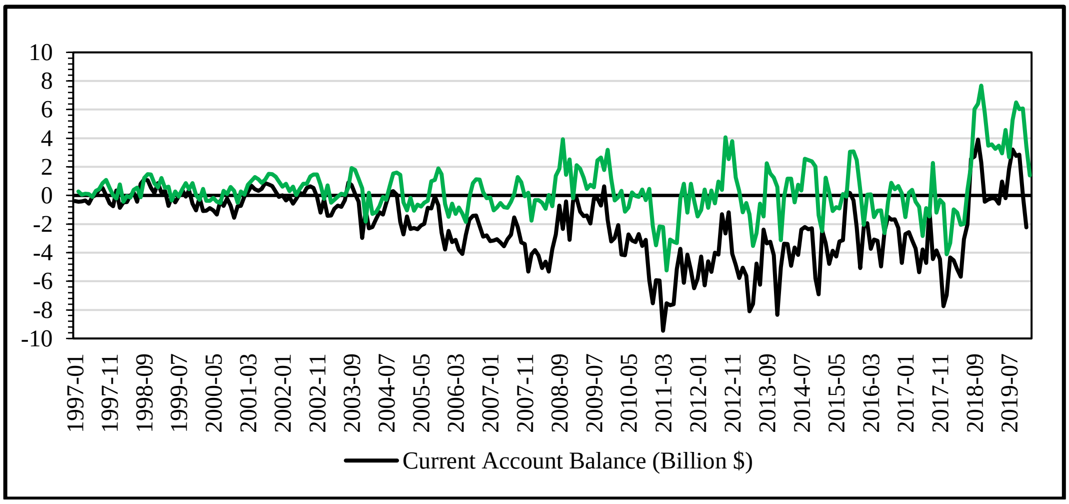

Figure 6. Current Account Balance (Billion $)

Source: (TCMB EVDS, 2020).

Another factor that lead to increase the risk of Turkish energy security is low level of investment especially before 1980's liberalization period. In conjunction with insufficient capital stock of private equity, weaknesses in the judicial system, excessive bureaucracy, regulatory risks, deficiencies in technological improvement, high inflation, political and macroeconomic uncertainties has discouraged energy sector investments and lead to a state led oriented market structure has come out before 2000 period. Insufficient energy investments have taken effect on low level of domestic energy production, high cost and particularly high rate of foreign dependency in primary energy consumption (Energy Charter, 2007: 12).

Demand for energy has been increasing due to the economic activities and population growth. Turkey's primary energy supply was 78.4 Mtoe in 2002 and raised to 144 Mtoe in 2018. It means nearly two fold increment. It is estimated that total primary energy demand will more than double by 2023 and expected to reach 200 Mtoe. Also total installed power capacity raised 31.8 GW to 91,3 GW and correspondingly electricity consumption spiked up 132.6 TWh to 290,9 TWh as of 2019. The current capacity is expected to reach 110 GW by 2023 to satisfy the increasing needs of domestic economy. In additions electricity, natural gas and oil demand will reach at 398-434 billion kWh, 59 BCM and 59 million tons respectively. In order to meet this growth in energy demand, Turkey needs 120 billion dollars of energy investment till 2023. So Turkish government has gave priority to the private sector for financing these investments and has taken necessary steps in that respect (create a conducive business and investment environment, stimulate energy investments, attract foreign direct investment to the Turkish energy market through the liberalization of the markets) to facilitate the investment environment (Hisarcıklıoğlu, 2010: 29; Erdin and Ozkaya, 2019: 4; Investment Office, 2019).

Lastly high level in energy intensity (total energy consumption for per unit of GDP), in other words low energy efficiency poses a risk for energy security. As the energy intensity of economy rises, it reflects a higher risk of supply security, because higher energy intensity (less efficiency) means more amount of energy you need to produce same level of GDP. It is also used to track progress on global energy efficiency. Improvements in energy efficiency help to reduce both supply risk (increase the supply source and decrease the reliance on fossil fuel) and demand risk (increase the efficiency of consumption and decrease energy intensity) in the context of energy security (APERC, 2007: 66). Improvement in energy efficiency or decreasing energy intensity is one of the best way to decrease consumption without harming the country's economic and social development. U.S. Department of Energy Plan reported that reducing the energy intensity of America's economy is the best way for reducing foreign energy dependency both in the near and long term'' (DOE, 2006: 8).

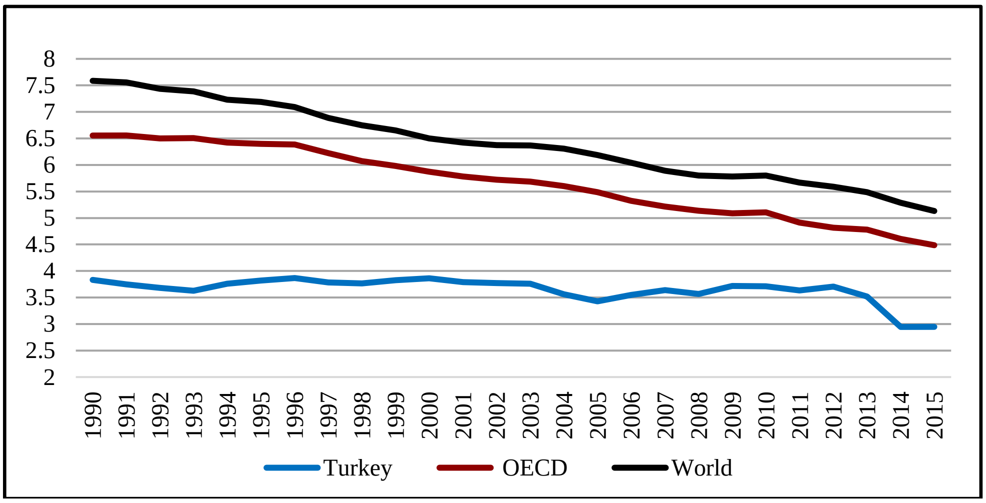

Figure 7. Energy İntensity Level of Primary Energy (MJ/$2011 PPP GDP)

Source: (World Bank Data, 2020).

According to figure 7, from 1990 to 2015 energy intensity level dropped 7,5 mj/$ to 5 mj/$ for world average and 6,5 mj/$ to 4,5 mj/$ for OECD average means 1,58% and 1,53% annual decrease respectively. However IEA set a target of 2,6% annual reduction in energy intensity from 2019 to 2030 to reach SDG 7.3 target but the World average has fallen short of this goal since it was announced. For example improvement in intensity is only 1,7% and 1,2% in 2017 and 2018 respectively. Although significant reduction in intensity level for World average or OECD countries, decrease in intensity for Turkish economy was improved slightly between whole period. Increasing efficiency (use of technologies that require less energy to have same quality of performance) does not always bring security in energy markets but it can help to reduce growing energy demand and indirectly effect energy supply security. Secondly energy conservation (any attempts to use less energy) would also helpful for security strategies. So Turkish economy has to increase energy efficiency in production and consumption, establish and increase efficiency of Energy Management Systems, support energy efficiency projects, developed national financial mechanism for energy efficiency, improve public awareness and has gave enough priority to conservation policies (Erdoğan, Gedikli, and Genç. 2018: 161-162; ECSSD, 2011: 4-5).

3. LITERATURE REVIEW

In this article we focused on "energy supply security" which means the ability of domestic economy to access energy resources by affordably, continuously and environment friendly manner. Insecurity is generally measured by risk indictors. On this basis in recent decades, many number of risk index (supply side or demand side, long term or short term, simple or composite) have been used. However there are no common indicators between researchers that comes to agreement. The literature (journal papers, official reports and other publications) on risk indicators is quite extensive and vary by country (developed or underdeveloped), by energy resources, energy mix or energy endowments. So there is a high degree of subjectivity in their construction. Most of the papers are country-specific where energy security for a country is analyzed. Therefore, it is needed the application of several indicators for a broader assessment and understanding of security. We can measure by using a simple indicator but in this case we may miss some aspects of energy security. Alternatively it is generally used a basket of indicators that represent the various dimensions of energy security. In this basket each of the dimensions are weighted according to their importance. We called this kind of index is a composite index. Composite indicators allow us to compare countries, monitor their performance in time trends and provide us policy messages. For example a composite vulnerability index was developed by the World Energy Council (2008) to monitor European countries long-term energy vulnerability (Badea, 2010; Kruyt, Vuuren, Vires and Groenenberg, 2009).

Composite indicators contains a-energy availability (diversification and geopolitical factors are key issues to reduce and better mitigate the risks of import disruptions), b-infrastructure (requires sufficient investment on power plants, transformation transmission facilities, pipelines, storage, electricity transmission lines to prevent shortages or block outs), c-prices (it determine the affordability of energy supply), d-societal effects (construct and operate energy system to meet basic necessities of life, alleviate poverty and social welfare), e-environment (due to carbon and other emissions that contribute to global warming and air pollution, energy systems promote sustainable economic environment), f-governance (it deals with government policies help to hedge against and mitigate short-term energy disruptions) and g-efficiency (energy systems help to reduce energy demand, energy intensity and improve energy security by improving technologies) factors. These factors identifies several sources of risks such as physical, economic, political, regulatory, social and environmental risk (Labenderia and Manzano, 2012: 7-8, Yang and Chen, 2015: 58-59, Lilliestam and Patt, 2012: 7-8). These risks in energy security concept are different, the considerations for the best response to supply disruptions have changed, and the implications for solutions are far more sophisticated. Another way to assess energy security is to use quantitative algorithms and models have already been established in some papers (IEA 2007: 47/55-58; Kruyt et al. 2009: 2169; Von Hippel, Savage and Hayes, 2011: 6715; Sovacool, 2011: 14).

In the literature there are many numbers of simple or composite indicators that used in the analysis of energy security. Energy intensity (energy use per unit of GDP), resources estimates, reserves to production ratio, diversity indices, import dependence, energy prices, political stability, share of zero carbon fuels, market liquidity, sectoral indicators like share of biofuels in road transport are example of simple indicators (USGS, 2000; Mulders, Hettelaar and Bergen, 2006; Feygin and Satkin 2004; Greene, Hopson and Li, 2005; APERC 2007; IEA 2004 and 2007; Awerbuch and Berger 2003; Alhajji, James and Williams, 2003; Awerbuch 2006; Lesbirel 2004; Stirling 1999; Datar 2000; Van Ruijven et al. 2008). On the other hand, supply/demand index, vulnerability index, concentration index e.g. Shannon-Wiener index, Lerner Index, Herfindhal-Hirschman index and IEA security index are examples of composite indicators (Gupta 2008; Bollen 2008; Jansen, Arkel and Boots, 2004; Scheepers, Seebregts, De Jong and Matters, 2007).

United Nations Development Program (UNDP) quantified the extend of vulnerability of Asia-Pacific region against oil price shocks on the basis of three dimensions; economic strength (balance of payments: current account, budget balance, import cover ratio and oil import dependence), economic performance (GDP per capita and oil intensity of GDP) and economic growth with low share of oil (real GDP growth rate and share of oil in primary energy consumption). Oil Price Vulnerability Index (OPVI) is measured by using principal component (PC) analysis; $PC_n = \sum_{j=1}^{m} a_{jn} n_j$ for all n where PC_n is the factor score for principal component "n", a_j is the factor loading of variable 'j' on principal component "n" and X_j is standardized variable 'j'. In expanded form for principal component 1, the equation will be $PC_1 = a_{11}x_1 + a_{12}x_2 + ...a_{jn}x_j$. Countries are ranked according to weighted dimension scores (Actual Value-Minimum Value / Maximum Value – Minimum Value) and composite OPVI.

International Energy Agency (2007), focused on energy security market concentration (ESMC) index such as Lerner Index, market share and Herfindhal-Hirschman index to measure of the physical unavailability. Because it is one of the four basic elements of security concept. Energy Security Market concentration is defined as; $ESMC = \sum_i S_{if}^2$ where S_{if} is the share off each supplier i in the market of fuel f defined by its net export potential. Values of ESMC changes from zero (perfectly competitive market) to 10.000 (pure monopoly). IEA also consider political stability of exporter country by $ESMC_{pol} = \sum_i (r_i * S_{if}^2)$ where r_i shows political risk score of country i and scaled from 1 to 3. In the formula if $ESMC_{pol}$ score is 0, it represents perfect competition with the best level of political stability and 30.000 score points a pure monopoly of a country with the worse level of political stability.

IEA include price changes to ESMC and labeled as ESI_{price} which sum of the products of $ESMC_{pol}$ for each fuel multiple with share of the fuel mix divided by total primary energy supply;

$$ESMC_{price} = \sum_f \left[\frac{ESMC_{pol-f} * C_f}{TPES} \right] \quad (1)$$

Where C_f shows consumption of fuel type. C_f / TPES ratio is the share of fuel mix in TPES and $ESMC_{pol-f}$ is stand for the Energy Security Market Concentration of fuel f. According to formula as the country is exposed to high concentration markets, it will be less secure.

International Energy Agency (2011) considered risks and resilience on the basis of imported and domestic sources and designed model of short term energy security simple indicators called MOSES. IEA focused on short term instead of long term. MOSES addressed two dimensions of security ''external factors'' deal with imported energy and ''domestic factors'' related with domestic production. Secondly they are analyzed in both risk exposure and resilience factors to measure ability of energy systems against disruptions or supply shocks. These are simple indicators that indexed energy security by primary resources like oil, coal, natural gas, hydro power, biofuels and nuclear powers. For these resources net import dependence, political stability, diversity of suppliers, proportion of offshore production, volatility of domestic production, average storage level, entry points, proportion of offshore production and energy intensity are used as indicators. At the end IEA assesed risk score for each type of resources and labeled them sequentially from A (low risk and high resilience) to E (higher risk and low resilience).

Yang and Chang (2014) use four A's approach in a simple frame as availability of resources (coal-oil-gas reserve-to-production (R/P) ratios), applicability of technology (energy intensity level, Gross efficiency of fossil fuel-fired power plants, total patents in energy industry) acceptability by society (share of China's CO2 emissions in global emission, China's SO2 emissions, China's volume of soot emission, share of renewables and nuclear energy in electricity generation) and affordability (growth rate of ex-factory price indexes for coal-oil-gas-electricity) for 1981-2010 periods. According to results China's energy security was improved between 1981-1985 but deteriorated for the 1985-2010 periods.

Le Coq and Paltseva (2009) introduce a security index designed to evaluate risks associated with the external supply of energy to the EU Member States. They combine measures of energy import diversification, political risks of the supplying country, risk associated with energy transit, and the economic impact of a supply disruption by energy types of oil, gas and coal. Results demonstrate that instead of using aggregate approach it would be better to measures risk by index and levels of supply risk exposure differ across countries and energy types.

Gnansounou (2008) introduced a composite index for new big consumer countries on the energy market to measure their vulnerability by using supply/demand weakness as proxy. The proposed index is based on several indicators such as energy intensity, oil and gas import dependency, CO2 content of primary energy supply, electricity supply

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weaknesses and non-diversity in transport fuels. Results indicate that vulnerability is changes across 37 industrialized countries and also solution suggestion are also different. For example low dependence on oil and gas imports could be achieved by increasing the share of coal that could result in increasing the CO2 content of the TPES. So each country has to develop their own energy strategies.

Grub, Buttler and Twomey, (2006) want to find out relationship between low-carbon objectives and security of electricity generation in UK by considering diversity of fuel source mix to represent one dimension of security and apply two different diversity indices to the range of electricity system scenarios produced by the UK government. The results show that low-carbon objectives are uniformly associated with greater long-term diversity in UK electricity generation.

Martchamadol and Kumar (2014) evaluate Thailand's security performance using the 25 ''Aggregated Energy Security Performance Indicator (AESPI)'' for the period 1986–2010. These 25 indicators are simple indicators like energy intensity, import dependency rate, electricity Access rate, per capita energy use, reserves to production ratio, share of renewable energy and loss in transmission lines. During 1986–1991 period's country's risk score reduced from high and continuing moderately from 1992 to 2009 due to energy conservation programs.

Savacool (2013) present an energy security index which measures national performance on energy security based on 20 metrics comprising a security index in the frame of availability, affordability, efficiency, sustainability and governance to measure international performance across 18 countries from 1990 to 2010. He ordered countries from top performer (e.g. japan) to worst performer (e.g. Myanmar) according to risk score. According to results majority of countries have worsen in terms of their security score. Second, although there is total deterioration in their risk score a great disparity exists between countries. Third, within different part of energy security there is tradeoff relationship between them. Lastly, policies toward enhancing energy security should be considered on both domestic and foreign policy context.

Lu, Zang, Cheng and Liu (2014) examined China's energy security from 2001 to 2010 by using ecological network analysis (ENA) model which is a general system oriented analytical tool to simulate the crude oil supply network in China and quantitatively analyze its security. According to results North and South America made the largest contribution to the security of the crude oil supply in China.

Birol (2020) aimed to measure the natural gas supply security in the EU member states and Turkey for 2015. According to the results Belgium, France, Germany, Italy, the Netherlands and Spain are the most successful countries about country diversification in natural gas imports. Compared with EU member states, Turkey is among the countries with a high risk of natural gas supply security.

Gökçe (2014) used Principal Component Analysis (PCA) in order to constitute the Energy Vulnerability Index of EU countries and Turkey. The results pointed high risk index score for EU countries and Turkey means that they are vulnerable against supply shocks.

Peker (2015) measured energy supply security of Turkey by using four sub-indexes that compose overall index and their weighting coefficients. The results indicate that Turkey has high risk score. For this purpose Turkey has to direct investments to domestic energy production and markets, regulate the electricity power market and emphasizes over renewable technologies that diversify the sources and decrease import dependency.

4. DATA AND ECONOMETRIC METHODOLOGY

4.1. Data

In this study we designed risk index for Turkish economy by four main energy resources; oil, natural gas, coal and renewables (consist of hydro, wind, solar and biomass energy) for the period 1980-2016. We retrieved data about energy consumption (million ton oil equivalent-mtoe), domestic production (mtoe) and energy import (mtoe) of yearly period from foreign trade statistics of Turkish Statistical Institute (TUIK), Ministry of Energy and Natural Resources Energy Balance Tables (1980-2018) and yearly oil and gas report of Energy Market Regulatory Authority (EPDK). Gross domestic product (GDP) is chain linked volume of yearly data (constant 2009) in Turkish liras.

4.2. Method

For this purpose we employed energy data to construct aggregate security index. In the literature existing security index has generally focused on fossil fuels (especially crude oil) and mostly on industrialized countries. Also there is some studies take into account for both short and long-term. But from all of these studies, there is no consensus on a set of relevant indicators. Time series data to directly assess trends in energy supply security are rarely seen in the literature. However we conduct supply security index method enable us to measures risk score by different energy source and time period. So our paper is important by providing security metrics to assess overall energy supply security in Turkish economy and for future policy making to assess weakness in energy supply. In this frame the objective of this paper is to evaluate a set of energy supply security indicators for Turkish economy between 1980-2016 periods including interrelated indicators that indexed as i = 1….4 as follows;

1) *Intensity level,*
2) *Net import dependency ratio,*
3) *Ratio of domestic production to total domestic consumption,*
4) *Geopolitical risk of source countries.*

By this way we get composite energy supply security index (CESSI) that is derived as the root mean square of the scaled values of four security of energy supply indicators (Gnansounou, 2008). CESSI provide us composite quantitative measure of supply security by taking into account four indicators and captures the sensitivity of the Turkish economy to developments in the international energy market. When we evaluate CESSI score, higher index means higher energy supply insecurity or vulnerability. We can describe four security of supply indicators according to four energy types (oil, natural gas, coal, renewables) that indexed as j =1 ….4 are as follows;

- E_{1O}: *Oil intensity,*
- E_{1G}: *Gas intensity,*
- E_{1C}: *Coal intensity,*
- E_{1R}: *Renewables intensity.*

Second strand assesed foreign dependency on imported resources of domestic economy as follows;

- E_{2O}: *Oil import dependency,*
- E_{2G}: *Gas import dependency,*
- E_{2C}: *Coal import dependency,*
- E_{2R}: *Renewables import dependency.*

Third group is related with demand/supply balance in which;

- E_{3O}: *Domestic oil production-consumption ratio,*
- E_{3G}: *Domestic gas production-consumption ratio,*
- E_{3C}: *Domestic coal production-consumption ratio,*
- E_{3R}: *Domestic renewables production-consumption ratio.*

Last group of indicators are deal with politic risk of source (export) country. We assesed them by using World Governance Index of World bank.

- E_{4O}: *Geopolitic risk for oil import,*
- E_{4G}: *Geopolitic risk for gas import,*
- E_{4C}: *Geopolitic risk for coal import and*
- E_{4R}: *Geopolitic risk for renewable import.*

Ultimately we can notionally express them as follows;

$$E_{1O} = \frac{Oil\ consumption}{GDP}, mtoe / gdp \qquad (2)$$

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$$E_{1G} = \frac{Gas\ consumption}{GDP}, mtoe / gdp \tag{3}$$

$$E_{1C} = \frac{Coal\ consumption}{GDP}, mtoe / gdp \tag{4}$$

$$E_{1R} = \frac{\mathrm{Re}\, newable\ consumption}{GDP}, mtoe / gdp \tag{5}$$

The energy intensity (E_{ij}; where i=1….4 represent security indicator and j =1….4 shows energy type) is calculated as the ratio of total energy consumption (energy type j) to GDP and expressed in mtoe/GDP (million ton oil equivalent). It gives us how much energy is consumed for per unit of GDP. Output is measured by inflation adjusted GDP called chain linked volume index (2009=100). The relative indicator associated with energy type i (Φ_{1j}) is evaluated as;

$$\Phi_{1O} = \frac{E_{1O} - Min(E_{1O})}{Max(E_{1O}) - Min(E_{1O})} \tag{6}$$

$$\Phi_{1G} = \frac{E_{1G} - Min(E_{1G})}{Max(E_{1G}) - Min(E_{1G})} \tag{7}$$

$$\Phi_{1C} = \frac{E_{1C} - Min(E_{1C})}{Max(E_{1C}) - Min(E_{1C})} \tag{8}$$

$$\Phi_{1R} = \frac{E_{1R} - Min(E_{1R})}{Max(E_{1R}) - Min(E_{1R})} \tag{9}$$

The relative indicator Φ_{1j} is determined as projection of energy type j for the 0-1 scale. *A low value of Φ_{1j} can be inferred as energy system is less vulnerable or more secure versus negative shocks.*

Second indicator is E_{2j}, the ratio of energy import to total primary energy consumption (TPEC). It shows share of imported energy in total energy consumption. Below is the import dependency ratio;

$$E_{2O} = \frac{Oil\ import}{TPEC} * 100, \% \tag{10}$$

$$E_{2G} = \frac{Gas\ import}{TPEC} * 100, \% \tag{11}$$

$$E_{2C} = \frac{Coal\ import}{TPEC} * 100, \% \tag{12}$$

$$E_{2R} = \frac{Renewable\ import}{TPEC} * 100, \% \tag{13}$$

The energy import dependency is expressed as a percentage. Similarly, the relative indicator for domestic economy that related with E_{2j} is Φ_{2j}. It is calculated as follows;

$$\Phi_{1Y} = \frac{E_{2O} - Min(E_{2O})}{Max(E_{2O}) - Min(E_{2O})} \tag{14}$$

$$\Phi_{2G} = \frac{E_{2G} - Min(E_{2G})}{Max(E_{2G}) - Min(E_{2G})} \tag{15}$$

$$\Phi_{2C} = \frac{E_{2C} - Min(E_{2C})}{Max(E_{2C}) - Min(E_{2C})} \tag{16}$$

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$$\Phi_{2R} = \frac{E_{2R} - Min(E_{2R})}{Max(E_{2R}) - Min(E_{2R})} \tag{17}$$

Owing to normalizing adjustment, we transformed the indicator Φ_{2j} to the [0-1] interval again in *which zero score is stand for the lowest value of the import dependency means to more supply security*. *On the other hand 1 score is signified to the country has the highest value and means to less supply security.*

Third indicator is indigenousness rate which is measured as the ratio of domestic energy production to total domestic energy consumption. An energy system of a country has to be resilient to any shock to function uninterruptedly. So adequate volume of domestic production is a better indicator of the country's capacity to overcome short-term supply disruption than strategic energy reserves. Ratio of domestic production to total domestic consumption (E_{3j}) is calculated as:

$$E_{3O} = \frac{Oil\ production}{Oil\ consumption} *100,\% \tag{18}$$

$$E_{3G} = \frac{Gas\ production}{Gas\ consumption} *100,\% \tag{19}$$

$$E_{3C} = \frac{Coal\ production}{Coal\ consumption} *100,\% \tag{20}$$

$$E_{3R} = \frac{Renewable\ production}{Renewable\ consumption} *100,\% \tag{21}$$

Where E_{3j} is defined as ratio of domestic energy production to total energy consumed in country. Unlike first two indicators, self-sufficiency rate is negatively related with supply security. *A high value of E_{3j} means that country has less vulnerable system or less insecure* to supply shocks. Relative indicator of Φ_{3j} associated with E_{3j} is calculated as below;

$$\Phi_{3O} = \frac{E_{3O} - Min(E_{3O})}{Max(E_{3O}) - Min(E_{3O})} \tag{22}$$

$$\Phi_{3G} = \frac{E_{3G} - Min(E_{3G})}{Max(E_{3G}) - Min(E_{3G})} \tag{23}$$

$$\Phi_{3C} = \frac{E_{3C} - Min(E_{3C})}{Max(E_{3C}) - Min(E_{3C})} \tag{24}$$

$$\Phi_{3R} = \frac{E_{3R} - Min(E_{3R})}{Max(E_{3R}) - Min(E_{3R})} \tag{25}$$

The value of relative indicator, Φ_{3j} is changed between 0-1 intervals. A lower value of Φ_{3j} means the most secure energy systems. On the contrary the higher value means lower value of the security indicator and hence point to more vulnerable energy system.

The last indicator is geopolitical risk. We calculated it on the basis of two factors: diversification source country and associated political stability of them. Jansen, Arkel and Boots (2004) advised Shannon diversity index to assess such risk as follows;

$$S = -\sum_i \left[h_i m_i \ln(m_i) \right] \tag{26}$$

Where 'S' is Shannon Diversity Index. In this study we assesed index of energy import by considering political stability of source country. Shannon index consist of two indicator in which h_i defines political stability in exporting country i. It ranges from zero (means highly unstable country) to one (means highly stable country).

Second part of index is m_i. It is the share of source country i in domestic consumption on the basis of subjected energy type j. The relative indicator of Φ_{4j} associated with E_{4i} is estimated as:

$$\Phi_{4O} = \frac{E_{4O} - Min(E_{4O})}{Max(E_{4O}) - Min(E_{4O})} \tag{27}$$

$$\Phi_{4G} = \frac{E_{4G} - Min(E_{4G})}{Max(E_{4G}) - Min(E_{4G})} \tag{28}$$

$$\Phi_{4C} = \frac{E_{4C} - Min(E_{4C})}{Max(E_{4C}) - Min(E_{4C})} \tag{29}$$

$$\Phi_{4R} = \frac{E_{4R} - Min(E_{4R})}{Max(E_{4R}) - Min(E_{4R})} \tag{30}$$

Geopolitic risk indicator is negatively related with supply vulnerability. Hence lower value for E_{4i} stand for high vulnerability against any supply shocks. Value of Φ_{4i} is again normalized to 0-1 interval in which zero score means *highest value of the selected security of supply indicator or least vulnerable. The value 1 is point to lowest value of the security and hence most vulnerable.*

In energy policy, higher energy intensity leads to more adjustment costs and negatively affects supply security. Also low rate of self-sufficiency in energy consumption means domestic economy would be more fragile against international energy markets. Diversification of energy source both in terms of suppliers (refers to the mix of different energy exporting countries) and supply routes (make a choice between pipelines or spot markets) has become one of the basics for ennsuring security. Especially lean on politically stable supply sources has more reduces the security risks. Contrary political instability or geopolitical uncertainty makes supply source and routes more insecure. Lastly increase in strategic reserves also would be rise resilience of energy systems against supply shocks.

Assessing a country's overall energy security by using individual indicators is not easy due to difficulties in synthesizing composite indicators. It would be better representing them in same units to enable comparison of different indicators. For this purpose each relative indicators, Φ_{ij} of different energy type was used to formulize composite energy supply security index (CESSI). It is derived as the root mean square of the four relative indicators. *Value of CESSI ranges between 0 and 1 in which zero means the country is the most secure against supply shocks and the value of 1 is showed to the country is the most insecure to negative supply shocks.*

$$CESSI = \sqrt{\frac{\sum_{i=1}^{4} \Phi_{ij}^2}{4}} \tag{30}$$

This index indicates composite quantitative measure of energy security better than simple indicators by taking into account the interactions and interdependences between the identified set of indicators. It provide us reaction of the economies to volatility in international energy markets.

5. EMPIRICAL RESULTS AND DISCUSSION

We have estimated the CESSI for Turkish economy based on annual data from 1980 to 2018 and then we plotted estimated values year by year. Firstly in the event of intensity level, we present relativeness indicator by type of energy j = 1 ….4 are as follows; Φ_{1O}: oil intensity, Φ_{1G}: natural gas intensity, Φ_{1C}: coal intensity and Φ_{1R}: renewables intensity. The relative indicator of Φ_{1j} is determined as projection of energy type j in the interval [0, 1]. A low value of Φ_{1j} means that country is less vulnerable or less "secure" according to energy types.

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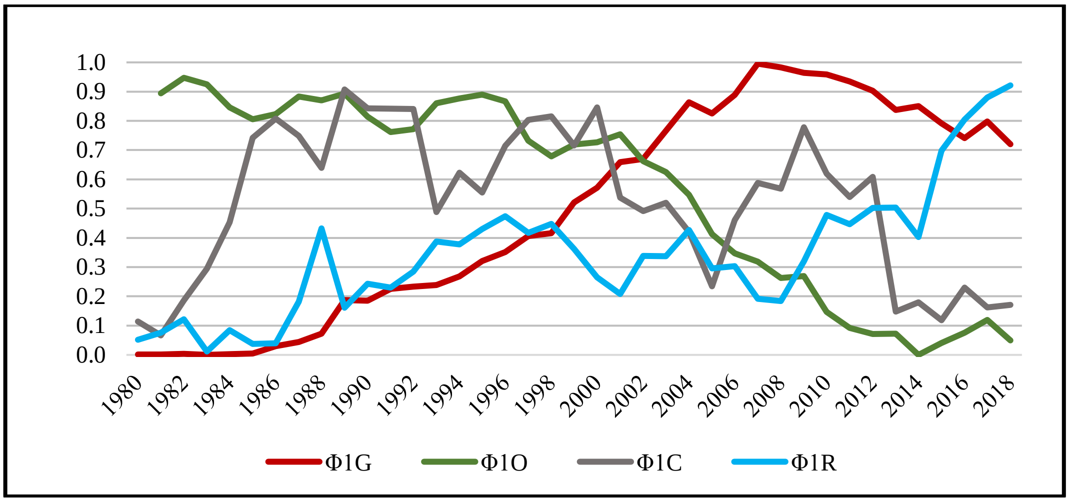

Figure 8. Energy Security of Supply Index Based on Energy Intensity (1980-2018)

According to figure 8, due to the ratio of natural gas consumed in Turkish economy to gross domestic product (GDP) is continuously increased from first import date of 1986, intensity indicator for gas was deteriorate till 2007 and reached maximum level of 32.6 mtep for per million GDP. During this period demand for natural gas has been increasing due to economic and population growth and rapid industrialization and urbanization. After that, share of natural gas in the energy mix declined from 34% (2007) to 29% (2018) according to long term national energy security plan. Correspondingly the value of relative indicator Φ_{1G} is decreased and make country is less vulnerable in the case of natural gas after 2007 period. When we look at oil indicator, Φ_{1G} it constitutes 28% of Turkey's total primary energy supply and an average of 35% of Turkey's final energy consumption. Although calculations show that the daily oil consumption grew at an average annual rate of 3.3% from 1980 to 2018, oil intensity for Turkish economy has decreased constantly from the beginning of the period. Strong competition from renewables, environmental concerns, bring more alternative fuel types into service has resulted decline in oil consumption for per unit of GDP. As it seen from figure 8, relative score of oil was decreased 0.89 to 0.049 means positively affect energy security.

In the third strand, consumption trend of coal has similar trend line with natural gas. It is one of the oldest fuels on earth and coal is a reliable fossil fuel that can be extracted at low cost. Coal is also popular as a fuel because of its production in many countries around the world and its common trade. In Turkey it is widely used in many household and industries. Turkish economy has exploited it's coal reserves increasingly and in 1991 coal consumption for per unit of GDP has reached 33.26 mtep/GDP. Coal is essential for electricity generation, cement plants, gasification and liquefaction process and steel production. During 1990's new technologies that commissioned in such sectors and cleaner manufacturing industries on sustainable coal utilization decrease coal intensity and it's relative indicator (Φ_{1C}) has lowered to 0.171 risk score as of 2018.

Lastly we have seen renewables. At first glance it has upward trend for the whole period. Renewable energies are *"domestic"* and cannot be imported such as wind, solar, geothermal or hydro power. Also its argued that renewables has become necessary for reducing the carbon emissions, slow down global warming and sustaining economic growth. The expansion of green technologies and renewable resources reinforces political measures for the realization of sustainable development goals across the world and it is a key item on the energy policy agenda, especially in developing countries like Turkey. In this manner, renewable energy consumption in Turkish economy raised nearly 20 times with regard to 1980 and consumption has risen faster than any other energy type. So increase in renewables consumption for per GDP has resulted with increase in Φ_{1R} intensity score means country is more vulnerable. But keep in mind that renewables are domestic resources they are not imported. So there is need for more advanced green technologies and more investment in research and development (R&D) pahse to decrase renewables intensity.

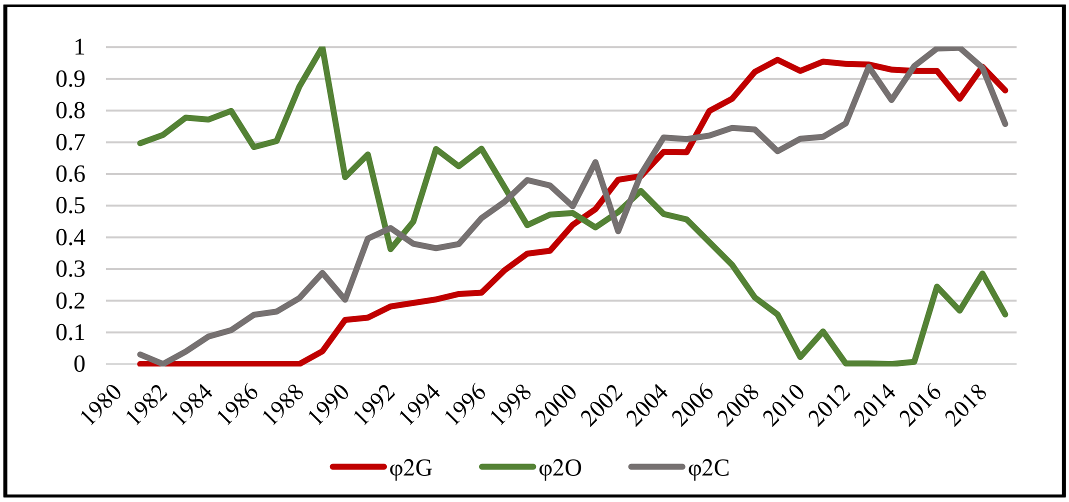

Figure 9. Energy Security of Supply Index Based on Import Dependence (1980-2018)

Secondly in the case of import dependency, we defined relativeness indicator as Φ_{2O} : oil dependency, Φ_{2G} : natural gas dependency, Φ_{2C} : coal dependency and Φ_{2R} : renewable energy dependency. As it seen from figure 9, we did not compute risk score for renewables due to its inherent physical properties.

The majority of countries in the world are net fuel importers, and fuel exports are highly concentrated on natural gas and oil. Ratio of imported energy to total energy supply in Turkish economy constitutes 0.85% for gas, 50.2% for oil, and 5.1% for coal at the beginning of the period. But in 2018 this figure has changed as 29% for gas, 34.4% for oil, and 15.3% for coal. Also share of imported energy in total supply increased 45% to 75% during whole periods. But renewable energy deployment could reduce energy imports because they are domestic resources. This means significant economic benefit, specifically for Turkey with large trade balance deficits and reduces dependency risk scores.

Similarly Turkish economy meets 92% of its oil need from imported resources as of today. But from 1980 to 2018 although volume of oil import increased 4 times, its share in total energy supply decreased 50.2% to 29%. Hence relative score for oil was 0.697 in 1980 and lowered to 0.156 means Turkish economy is less vulnerable in terms of oil. But as for coal and gas their share increased in the long term. Firstly share of natural gas in total primary supply was 1% in 1986 and jumped to 33% in 2014. Natural gas imports started in 1986 and its import dependence raised fast due to a substantial increase in demand. Gas demand was driven mainly by the power generation, rapid growth and domestic use. In 2007, Turkey generated 49.7% of its electricity needs from natural gas. Hydropower added about 18% and renewables contributed only 0.27%. On the other hand Turkey has been continued hard coal import and between 1980-2018 periods share of imported hard coal in total coal consumption soared from 5.1% to 60.2%. Only in 2018, Turkish economy imported nearly 4.5 billion usd worth of hard coal from various countries. This number was just around 300 million usd during 1990’s. So this figure implied that relative risk score for import dependence increased 0.030 to 0.758 means makes Turkish economy more vulnerable and risky against negative supply shocks in context of coal energy.

Third strand is self-sufficiency (figure 10) rate that shows ability of domestic resources to meet total energy consumption. We indicate its relativeness indicator according to four type of energy as follows; Φ_{3O} is oil sufficiency, Φ_{3G} is natural gas sufficiency, Φ_{3C} is coal sufficiency and Φ_{3R} is renewable energy sufficiency. As we stated above total domestic production was 17.358 mtep in 1980 and with this number Turkey had met 54% of its gross supply by local resources. In 2018, domestic production was increased to 39.675 mtep but Turkey was met only 25% of its energy needs from domestic resources. For the entire period, while energy supply was staggering near six fold increase but domestic production has raised only 2,2 times. Therefore Turkey has become more and more dependent on foreign resources every year because of insufficient domestic production. According to Ministry of Energy and Natural Resources statistics, only 8% of crude oil demand and 2% of natural gas demand have been met by local resources as of 2018. As the increase in its energy consumption has outpaced domestic production, Turkey has become a net energy importer from year to year.

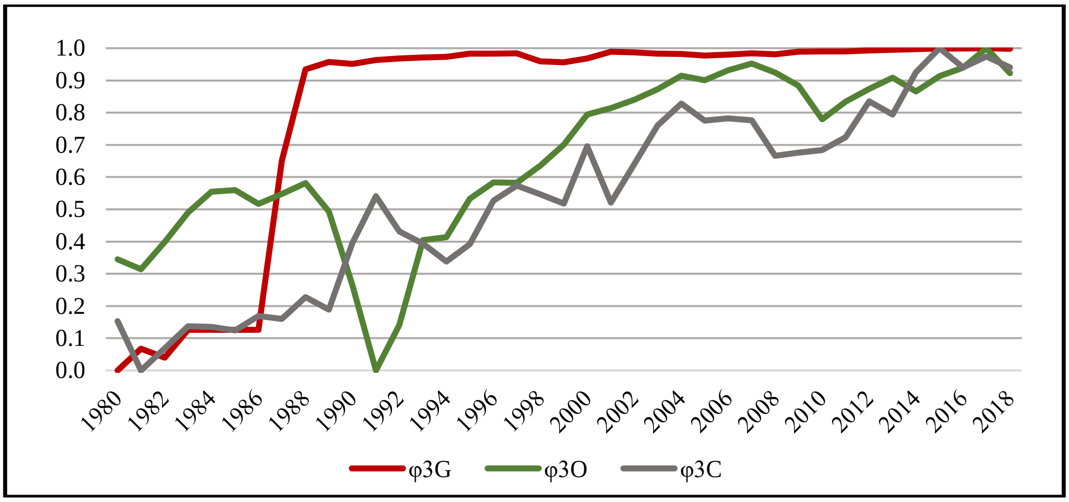

Figure 10. Energy Security of Supply Index Based on Self Sufficiency (1980-2018)

As can be seen from figure 10 relative indicator based on self-sufficiency raised continuously from 1980 to 2018. Risk score was increased 0.067 to 0.998 for natural gas, 0.313 to 0.922 for oil and 0.153 to 0.940 for coal means more vulnerable an economy is to international energy developments.

Last indicator is diversity index. We use this index to assess geo political risk (political stability) dimension of energy security that based on political risk of exporter country and its share in the import of domestic energy use. We show their relativeness indicator according to energy type as; Φ_{4O} is oil import risk, Φ_{4G} is natural gas import risk, Φ_{4C} is coal import risk and lastly Φ_{4R} is renewable energy import risk. But we exclude renewables which are consist of solar, wind, biomass, hydro and geothermal energies due to they are indigenous resources. Time series for relative indicator of geopolitical risk starts from 2000 because of data availability.

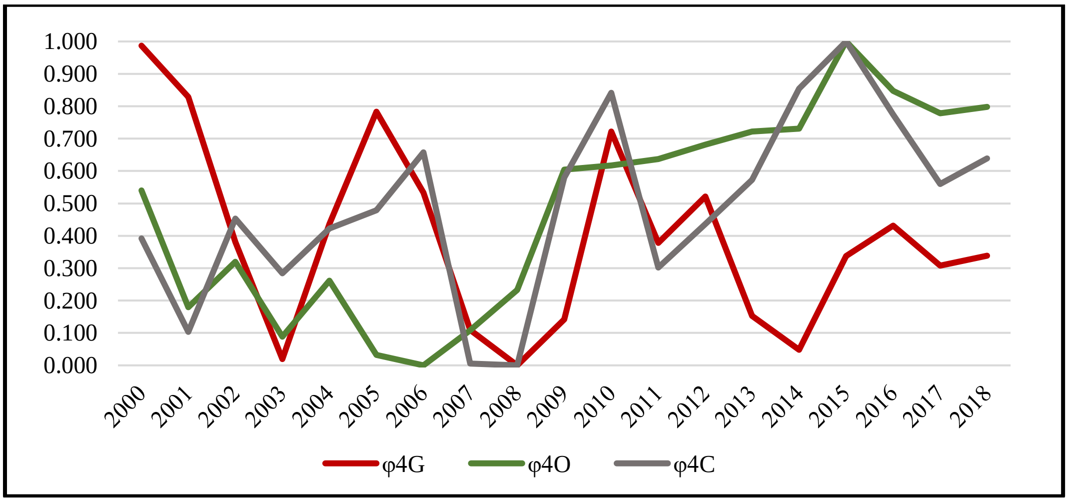

Figure 11. Energy Security of Supply Index Based on Geopolitic Risk (1980-2018)

As we mentioned before this indicator is negatively related with supply security which means that a lower value for E_{4j} can be inferred high vulnerability against negative supply shocks. The value of Φ_{4j} is adjusted again to 0-1 interval. The value of 0 refers to least vulnerable system and the value 1 indicates the most vulnerable one. As could be seen from figure 11, oil and coal indicators have moderately upward trend. According to our estimates,

Φ_{4C} and Φ_{4O} score stepped up 0.392 to 0.639 and 0.541 to 0.798 respectively. However Φ_{4G} was 0.998 at the beginning of the period and lowered swiftly to 0.020 by 2003. From 2000 to 2003, Turkey had decreased its natural gas import from Russia proportionately 68% to 59%, decreased from Algeria 27% to 18% but raised from Iran 1% to 17%. This means more diversified import from source country. In the advanced years, Turkey started gas import from Azerbaijan and raised to 15%, decreased again Algeria and Russian share till 9% and 46% respectively. In line with these more diversified figure, Φ_{4G} score was end up with 0.338 which is lower than oil and coal.

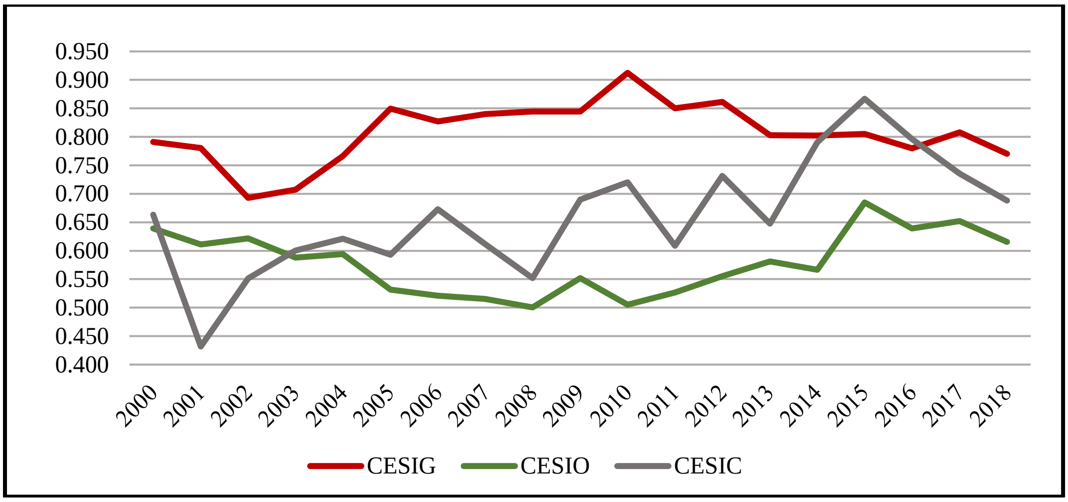

Figure 12. CESSI (2000-2018)

At the last stage of the analysis we have finally estimated CESSI score (figure 12) for oil, gas and coal. Firstly natural gas supply security profile was relatively wreaked during all period in which its score was nearly unchanged 0.791 to 0.770 means very small improvement in supply security. During whole periods gas production is far behind domestic needs and share of in the energy mix is still high. So CSSI indicator for gas provide quite limited protection against supply shocks. Similarly oil has contribute very few recovery to supply security by decreasing from 0.639 to 0.615 due to its share in energy import and low self-sufficiency rate. If we consider coal, contrary to other energy type, its trend has been consistently rise for the period 2001-2015 and doubled from 0.430 to 0.870. From past to present coal is widely used for power generation due to wide and cheap resource of energy for Turkey. Besides contrary to oil or natural gas, the world coal reserves are present in around 80 countries. Turkey is evaluated as being at medium levels in terms of the reserves and production amounts of low calorie lignite. Turkey is the third-largest lignite producer in the world producing 7% of all lignite. The net calorific value of Turkish lignite is lower than hard coal but hard coal domestic production is far behind demand. As of 2018, hard coal reserves stood at 0.55 billion tones and 10.9 billion tones for lignite. Based on these reserves, coal sector produced 1.1 million tons of hard coal and 85.2 million tons of lignite in 2018. This being 44.5% of domestic energy production and used mostly for power generation.

In power generation coal was accounted 24% in 2001 and spiked up to 37% in 2018. As of the end of 2018, the power plant installed capacity dependent on coal was 18,997 MW, and this is equal to 21.5% of the total installed capacity. Coal-fired power plants had an installed capacity of 19.700 MW at the end of 2018 (22.2% of total capacity). Hard coal-fired power plants (based on imported hard coal) capacity was 9 600 MW (10.8%) and the capacity using domestic lignite was 10 100 MW (11.4%). Because coal imports (hard coal) have grown steadily over the last forty years and outpaced lignite after 2011 and stood at 38 million tons in 2018. As a result after 2001, foreign dependency rate in supply has increased and domestic production rate in consumption has decreased. So CSSI score for coal showed that it has affected energy systems negatively in Turkish economy.

6. CONCLUSION

Turkish economy can be defined as a dynamic emerging market with 82 million young and growing populations with nearly $771 billion ($9.289 per capita) GDP as of 2018. It is one of the fastest growing economies among EU and OECD member countries. Turkey has witnessed significant economic growth for the last decades. With this number, Turkey has the 17th. highest GDP in the World. However from past to present energy supply/demand balance of domestic economy could not provide properly because of rapid economic growth, dynamic and young population, high urbanization rate, poor national energy resources, underinvestment in energy infrastructure, insufficient utilization from renewable resources and inadequate energy production (petroleum and natural gas) against total demand. Majority of the primary energy need is met by imported natural gas, followed by hard coal and petroleum. Also Turkey's energy demand is expected to continue its increasing trend. Due to this figure Turkey has a dependency rate on energy imports of 75% and energy imports are 1.5 times the size of the current account deficit, and therefore lead to increase Turkey's economic vulnerabilities.

On that note these imperfections have derived economy depend highly on imported energy and Turkey faced unbalanced and unsustainable production/consumption pattern in the energy field. The growth in primary energy consumption greater than the growth in primary energy production leading to a widening energy shortage year by year. As of 2018, only 25% percent of total energy consumption was met by national resources. However this composition poses high risk as if there is any interruption on energy supply it will inevitably disrupt output, degeneration of macroeconomic stability, rising inflation, unemployment or foreign trade deficit. According to Energy Security Risk Index report (allows us to compare energy security risks between countries and shows the change in energy security risks over time) 2018 which is issued by Global Energy Institute, Turkey's total risk score was 1,198 for 2016. This means seven grade fall back according to 2011 and put it in 22nd place. During 1980's Turkey was ranked number six and it risk scores were 10% below the OECD average. But after first natural gas import in 1987, Turkey's score jumped from 826 to 978. This means Turkey's risk score went from 7% below the OECD average to 11% above and this gap has keep grown since then.

In this context, Turkey has focused deeply on energy security issues and developed active policies to ensure the flow of energy sources to the Turkish energy markets without any interruption. For this pupose there are many alternatives at confidential level. Energy demand growth is inevitable due to economic activities and population growth and energy resources are scarce and subject to depletion. So each country (importing country) have to secure energy supply as much as possible.

In this sense Turkey has many policy alternatives. Diversify its energy supply routes and source countries as well as new energy types, increasing the share of renewables (Solar, wind, jeo or bio power) and extending resource portfolio to include the nuclear power in its energy mix would be very helpful.

Secondly we have to deal with energy markets to perform efficiently. Efficient markets means affordable energy price, higher quantity, more competition, more variety and higher quality products. Turkey needs for establishment of a well-functioning and transparent wholesale market. Traditionally there are very few companies in energy sector across world countries due to market barriers. For this purpose reforming energy sectors, regulating energy markets to strengthen competitiveness, opening energy markets to more private wholesale and retail companies, alleviating bureaucracy for energy investments, making the national energy regulators more effective and facilitating of the cross border energy trade (growth in energy trade is directly related to the networks and supply lines) to became energy hub are regarded as useful measures to achieve more efficient, customer oriented and competitive energy markets.

Thirdly increasing exploration activities as a priority goal to reduce import dependency in coal, oil and gas, utilizing more from domestic resources, increasing control on existing energy resources are important actions to decrease foreign dependency.

Four, Turkey could implement various measures to better cope with supply disruptions and significantly mitigate their effects. For instance encouraging investment on domestic energy infrastructure, increasing research and development expenditure, promoting energy efficiency investment, developing different types of energy technologies, increasing emergency storage (LNG, crude oil) capacity, overhauling electricity transmissions lines and generation systems would be provide us more efficient and resilience energy systems. Investing in energy transmission and distribution channels, as well as improving infrastructure will improve energy efficiency and reduce energy costs.

Energy efficiency has critical position in energy security. In this regard designing Energy Management Systems, creating financial mechanism to credit energy efficiency projects, availing efficiency projects from public funds, preparing handbooks or quality standards to make more understandable of technical and financial aspects as well as administrative and institutional structure for efficiency system, following the international energy efficiency improvements to stay update, raising public awareness about energy efficiency and pursuing sustainable energy policies are essential measures that have to be taken.

Five, Turkey is a natural energy corridor between energy producers (Middle East and the Caspian basin) and energy consumers (European countries) due to its geographical location. Therefore Turkey has the potential to become an important energy bridge between East and West and become energy hub (trading center) for oil and gas transported through pipelines. Turkey should benefit from the high potential of being the 'energy corridor and energy hub to improve supply security. Participating in transportation stage of the oil and natural gas projects related to the Caspian Sea and the Middle East regions, increasing the capacity of strategic oil and natural gas underground storage facilities, building new LNG terminals, FSRU and LNG re-gasification facilities, increasing upstream production capacity, increasing fuel flexibility in order to provide usage of alternative energy sources in power generation. Besides expansion of this role lies with maintaining good neighbor relations with source countries.

As a result for the dynamic and high growth potential of Turkish economy cannot be sustainable and function properly unless pay enough attention and pursuing energy supply security policies. By implementing various energy security measures and policies, Turkey have an opportunity to better cope with supply disruptions and significantly mitigate their negative effects.

DECLARATION OF THE AUTHOR

Declaration of Contribution Rate: The author contributes the study on his/her own.

Declaration of Support and Thanksgiving: No support is taken from any institution or organization.

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