Application of a Multi-Criteria Integrated Portfolio Model for Quantifying South Africa's Crude Oil Import Risk

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Abstract

The availability of secure energy resources at sustainable quantities and affordable prices is fundamental to South Africa's current objective of enhancing and sustaining its current growth trajectory. Economic reforms, since the early 1990s, have led to the economy growing at an average rate of almost 5% per annum. A major consequence of this strong growth is the rapid increase in domestic demand for oil energy. With small amounts of proven oil reserves, the rise in oil demand as an essential energy source has prompted an increasing reliance on external sources for domestic crude oil supplies. High oil prices, the extent of proven oil reserves, instability in major oil producing regions and the rise in 'oil-nationalism' have raised serious concerns about the security of South Africa's oil supplies. In this context, a comprehensive understanding of oil import security risks is critical as it will guide in the formulation of energy policy framework aimed at alleviating the impact of oil import risks. This study utilises portfolio theory to provide quantitative measures of systematic and specific risks of South Africa's crude oil imports over the period 1994 to 2007. It explains the relationship between supply sources diversification and oil energy security risks, and highlights the impact of different crude oil import policy adjustment strategies on the total crude oil import risk for South Africa. The results for the adjustment strategies show that: (a) a policy of having the same quantity of oil imported every month or a constant quantity of oil imported from the supply regions reduces both systematic and specific risks of oil import portfolio, and (b) a reduction in specific risks of South Africa's oil imports can be achieved if some of the Middle Eastern supplies can be diversified to less risk regions of Europe, North America and Russia.

JEL classification: C44, F10, G11, 013, Q40

Keywords: Oil Import Risks, Portfolio Theory, Analytical Hierarchy Process.

1 Introduction

Accounting for about 35% of global energy demand, crude oil forms the major fuel source for the transport sector of most countries, is a significant source of energy for firms in the manufacturing sector, and is a vital raw material for a number of industries such as those in petrochemicals. Global consumption of petroleum increased from just over 58 million barrels per day (bbl/day) in 1983 to about 85 million bbl/day by 2006. The strong growth in global oil demand is expected to

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continue for some time with global crude consumption forecast to reach 118 million bbl/day by 2030 (Energy Information Administration (EIA), 2007). Rapid expansions in the industrial capacities of a number of economies in Latin America (notably Brazil, Argentina and Venezuela) and high growth rates of non-Organization for Economic Co-operation and Development (OECD) Asian economies (mainly India and China) has contributed substantially to global consumption of petroleum. Rising uncertainty over when oil production will peak, ambiguity over actual estimates of world oil reserves, and the possibility of a supply crunch due to unanticipated excess demand are factors that have firmly placed the concept of energy security on the agenda of many countries that heavily rely on crude oil imports.

For South Africa, the current macroeconomic framework aimed at providing an enabling operating environment that enhances the economy's productive capacity and the ability to generate sufficient levels of both domestic and foreign capital investment, is significantly dependent on the country's capacity to guarantee the supply of secure, uninterrupted and competitively priced energy resources. The security of energy supplies takes on even more relevance when one considers that South Africa is Africa's largest consumer of primary energy and accounts for almost a quarter of total oil consumed in the continent. With petroleum reserves along its western and southern coastlines estimated at a mere 16 million barrels, South Africa remains heavily reliant on large imports of crude oil to meet its growing demand for liquid fuels (Department of Mineral and Energy (DME), 1998). Over the period 1994 to 2006, South Africa's import of crude oil averaged a growth rate of 3%, and accounted for over 55% of total oil consumed domestically. Trade data from the South African Revenue Service (SARS) (2007) shows that South Africa's supplies of crude oil imports are dominated by a small number of countries. In 2006, 35% of South Africa's crude oil imports were sourced from Saudi Arabia, 29% from Iran, 13% from Nigeria, and about 4% from Angola. The remaining 19% was sourced mainly from the Russian Federation, a variety of countries in Africa (mainly Libya and Gabon) and the Middle East (mainly Iraq, United Arab Emirates, Yemen and Oman).

Two important trends make the quantification of the risks associated with South Africa's crude oil imports necessary. First, the country's demand for crude oil has increased since 1994, and due to strong expansions in the transportation and mining sectors,[1] growth in total oil consumption has averaged an annual rate of almost 2%. Second, South Africa is highly dependent on oil import supplies from countries located in the Middle East and Africa, two regions prone to a high degree of geopolitical instability. Viewed within the context of increased international competition in securing crude oil supplies and current geopolitical tensions, South Africa's growing demand for oil and its significant reliance on oil supplies from countries in these two regions raises concerns. Depletions in the oil stock of the United States and Europe, sharp increases in demand for oil in the expanding demand centres of India and China, growing tensions in the Middle East (as a result of the war in Iraq and Iran's nuclear aspirations) as well as potential disruptions to oil drilling operations in Nigeria's volatile Niger-Delta region are among the key factors that have added to rising concerns regarding the capacity of South Africa to meet its oil energy demand in the event of significant disruptions to the production and/or supply of crude oil. Given these issues, the following questions are pertinent:

- What do trends in South Africa's oil imports imply in terms of the country's oil energy security risks?
- How can the relationship between international crude oil prices and South Africa's crude imports be analysed?
- What is the nature of South Africa's oil import risks and can they be quantitatively measured?

[1] The energy intensive activities in the mining sector are mainly linked to heavy industries, minerals beneficiation and metals production.

- Can the government adopt a diversification strategy to mitigate against oil import risks?
- What impact can a diversification strategy have on South Africa's oil import risks, or more specifically, which strategy reduces risk by the most magnitude?

To answer these questions, this paper develops an empirical framework that examines the relationship between diversification and oil energy security risks, quantifies South Africa's oil import risk and provides a foundation for exploring the impacts that potential diversification strategies could have on aggregate oil security risks. In this way, the paper makes two contributions to existing literature on energy security risks in South Africa and Africa as a whole.

First, we address the dearth of detailed research on the concept of oil energy security for oil-importing Sub-Saharan African nations. Most empirical studies quantifying crude oil import risks have either focused on developed oil importing economies (see, for example, Lesbirel, 2004) or emerging market economies in the Asia-Pacific region (e.g., Wu *et al.,* 2005). To the best of our knowledge, no published study has developed an empirical framework for quantifying the risks associated with oil imports of an open, middle income and oil-importing African economy such as South Africa's economy. Yet, countries such as South Africa represent a unique case capable of shedding light on how a clear assessment and understanding of energy security risks can contribute to policy decisions on determining the appropriate role of different energy sources within a given energy resource portfolio.

Second, the study incorporates qualitative judgments into a risk index framework, that reflect the role/impact of suppliers' export policy, international oil prices and geopolitical factors on oil import risk. The empirics of the qualitative judgments are developed and examined using the analytical hierarchical process (AHP) (Saaty, 1980; 1994). Integrating the AHP in the risk index framework, to the full examination of risks allows for both objective and subjective assessment of diversification strategies that could mitigate against South Africa's oil import risks. In summary, the added value of this work lies in its direct quantification of the oil import security risks associated with South Africa's crude oil imports using portfolio theory, where risks associated with the different supply sources are generated using AHP. We are unaware of any parallel work in South Africa, and indeed the rest of Africa that has applied portfolio theory and the AHP in examining and quantifying oil import risks.

The rest of the paper is structured as follows. Section 2 provides the literature review on the concept of energy security, with a specific focus on South Africa's oil energy security. Section 3 presents the data and methodology used to derive South Africa's oil import diversification index. Section 4 discusses the results of the analysis of South Africa's oil import risks. Section 5 provides a discourse on the impact of import strategic policy scenarios on the estimated risk index model. Conclusions are presented in Section 6.

2 Literature Review and an Overview of South Africa's Oil Energy Security

The concept of energy security is relatively broad and encompasses a variety of threats to supplies of different energy sources (notably oil, natural gas and electricity). From the perspective of net-energy importing countries, energy security is defined as the availability of a regular supply of energy resources at affordable prices (IEA, 2001). This allows for the analysis of the concept of energy security in five dimensions: *physical, economic, social, environmental, and time* (European Commission, 2001). The *physical* dimension looks at energy security in the context of potential disruptions when an energy source is exhausted or stopped, either temporarily or permanently (Costantini *et al.,* 2007). Energy price volatility accounts for the *economic* dimension of energy security and is largely borne out of the reaction of market players to perceptions over the direction of energy supplies and prices. For instance, if the demand for a particular energy resource is anticipated to grow substantially over a period of time, the lack of investments in expanding supply infrastructure and productive capacity of that energy resource could fuel concerns that demand will outstrip supply. Perceptions about future shortages could trigger increased demand for the energy resource for stockpiling purposes, thereby bidding up of the price for that energy resource.

In cases where a particular energy source forms a vital input in the production process of important sectors of an economy, both the *physical* and *economic* aspects of energy security introduces the *social* dimension of energy security. Instability or disruptions to energy supplies that result in either product shortages or energy price shocks could result in substantial social disorder.[2] Rising awareness about the global climate and environment has, in the past two decades, led to energy security being increasingly interwoven with climate and environmental concerns about how factors such as accidents (oil spills, problems with nuclear reactors) and polluting emissions (greenhouse gas emissions from the heavy use of coal and other fossil fuels) negatively impact the earth's ecosystem. The *time* dimension of energy security can be assessed from two perspectives, that is, the *short*-term and the *long*-term. The former is primarily concerned with the disruptive impact of effects such as unanticipated supply disruptions or price hikes, while the latter focuses on ensuring that the objective of maintaining stable and consistent economic growth (and development) is enhanced by the availability of energy supplies at sustainable quantities and affordable prices (Costantini *et al.*, 2007).

As the world's preeminent source of energy and the most tradable fuel, crude oil dominates the notion of energy security. The current energy security system of the world's industrialised countries, created in response to 1973 oil crises, has as its main element, the implementation of a coordinated and collaborative approach in developing strategies to offset potential major supply disruptions that could threaten global stability and economic activities (Yergin, 2006). While the dominance of crude oil in debates on the concept of energy security declined between the 1980s and early 1990s, the recent surge in global crude oil demand and prices means that just as in the 1970s, crude oil dominates renewed debates on defining energy security.[3] Whereas the widely used definition of oil energy security focuses on the availability of sufficient supplies at affordable prices, the precise meaning of oil energy security remains ambiguous as it differs from one country to another.

For oil producing countries that generate the bulk of their income from oil exports, the concept of energy security will emphasise the need to ensure the "security of demand" for their exports. For oil importing countries, the new notion of energy security is underpinned by the extent of two key factors: 'oil dependency' and 'oil vulnerability'. In its broadest form, oil dependency relates to a country's' reliance on foreign imported quantities of crude oil. The problem of dependency on foreign oil not only varies with imported quantity, but also with the stability of the oil market, the number of suppliers in the market, the energy intensity (measured by the quantity of oil needed per unit of output) in the economy among other factors.

The extent of South Africa's oil dependency can be measured using four main indicators: *oil self-sufficiency*, *intensity of oil use in energy consumption*, *energy intensity of Gross Domestic Product (GDP)*, and *per capita oil consumption*. The oil self-sufficiency index measures oil production (less consumption) relative to total oil consumption. A value of -1 is indicative of a country's total reliance on imported crude while a positive value means a country is relatively self-sufficient in the production of crude oil. The intensity of oil use in energy consumption measures the share of oil in a country's total primary energy consumption. A value of 1 is obtained where oil forms the only energy source, and zero where no oil is utilised in the generation of energy. Table 1 shows that South Africa has a relatively high level of reliance on oil imports, an indicator that the country is quite

[2]In the first quarter of 2008, authorities in Cameroon, Cote d'Ivoire, Mauritania, Senegal, Burkina Faso and Mozambique were confronted with a wave of often violent social unrest caused by soaring costs of fuel and staple foods. While the African continent is a major oil producer, policymakers have warned that continued increases in the cost of crude oil and its adverse impact on poor households (in the form of higher public transport and food prices) pose significant threats to Africa's growth, peace and security.

[3]The energy policy debate has also expanded and now takes into account potential disruptions to the supply of other energy forms including electricity and fuels derived from natural gas, coal and nuclear energy.

vulnerable to oil supply disruptions. However, a country's vulnerability to oil shocks (either in the form of higher prices or major disruptions to oil supplies) depends not only on oil-self sufficiency, but also the extent to which oil is used in energy production (Asian Development Bank (ADB), 2005). Since the 1980s, South Africa's use of oil in meeting its energy demands has remained relatively stable with its intensity of oil use in energy consumption averaging 0.2 between 1994 and 2006 (see Table 1). For its size and population, this value is low when compared to global levels and can be attributed to the country's endowment with vast coal reserves.[4]

Although South Africa's intensity of oil use has been stable and relatively low compared to other middle-income countries, its energy intensity of GDP (and *per capita* oil consumption makes the country one of the most energy intensive economies among middle-income oil importers (see Figures 1 and 2).

South Africa's lack of significant oil reserves means that its production of natural gas and crude oil remains very limited. Domestic demands for liquid fuels are met via supplies derived from two sources: (a) imported crude oil, and (b) a highly developed domestic synthetic fuels industry dominated by two firms: SASOL and PetroSA.[5] Significant socio-economic reforms coupled with government's commitment to modernise the economy have, since 1994, led to a period of relatively robust growth of the South African economy. Linked to this growth is the strong increase in the demand for oil energy, an increase reflected in the growing importance of crude oil as a major energy source and the increase in the country's total consumption of crude oil. In 2006, South Africa consumed 23.2 million tonnes of oil (approximately 505,000 bbl/d) compared to 16.7 million tonnes in 1990 (see Figure 3).

With oil imports accounting for a relatively significant share of this consumption, South Africa's energy security risk can be viewed as being linked not only to its oil dependency, but also its oil vulnerability. The country's high dependence on the Middle East region for its oil imports raises the prospects that the country will be adversely affected by potential oil supply shocks in that region (see Figure 4).

With the majority of oil imports sourced from the Middle East region (notably Iran, Saudi Arabia, and Kuwait) and with Nigeria, Venezuela and Angola gradually becoming significant sources of oil imports, South Africa faces a multiplicity of possible risk factors that could cause disruptions to its oil imports. Amongst others, factors that pose risks to the security of oil imports include:

1. concerns about how Iran nuclear ambitions will affect its oil exports;
2. the ongoing war in Iraq and its impact on socio-political stability of the Middle East;
3. the threat of attacks on oil facilities in Nigeria's Niger-Delta region; and
4. the potential effects of underinvestment if countries like Venezuela implement a full nationalisation of their oil sectors.

In this respect, the formulation and implementation of policies aimed at ensuring energy security is quite difficult as the uncertain interactions of the above threats creates ambiguity over the probability of disruptions occurring. While government can not completely eliminate the risks associated with the threat of supply disruptions, it can still formulate appropriate policy measures to minimise risks and effects associated with supply disruptions. Thus, it is recognised that a proper evaluation of oil import risks can provide a useful analytical tool for policymakers seeking to design coherent and effective energy security policy.

[4] In 2003, the intensity of oil use for the East Asian sub-region (made up of the People's Republic of China, Hong Kong, Republic of Korea, Mongolia and Chinese Taipei) was estimated at 0.31. The nations of Indonesia, Philippines, Singapore and India which share similar economic characteristics to South Africa recorded estimates of 0.5, 0.6, 0.9 and 0.3, respectively (ADB, 2005).

[5] The acronyms SASOL and PetroSA respectively stand for Suid Afrikaanse Steenkool en Olie (or in English, the South African Coal and Oil Company) and Petroleum Oil and Gas Corporation of South Africa Property Limited . See the EIA's Country Analysis Brief on South Africa (2007) for details about the output and technology of both SASOL and PetroSA.

3 Data and Methodology

3.1 Data

Oil statistics are often utilised for purposes of international comparisons, construction of regional aggregates and generation of global oil balances. It is therefore vital that appropriate and comparable data be chosen for such analysis. Also of importance is the need to ensure that the data is based on appropriate classification of different fuel types, and that the use of a common unit of measurement, derived from the application of a suitable conversion factor, is adhered to. These factors are important for the accurate comparison and aggregation of data, and form the basis on which sound policies relating to oil energy use can be formulated (Karbuz, 2004).

For empirical studies that have utilised quantities of traded crude oil in their analysis, barrel of crude oil is the standard unit measure employed. For South Africa, data on the country's crude oil imports from all supply origin[6] are recorded in kilograms. This implies a need for the application of an appropriate method to convert the quantities of oil imports into barrels. The choice of such an appropriate conversion method is made difficult by two factors. First, there is the lack of global consensus on a common convention in measuring oil. Second, the use of a generic version to relate volume and weight based measures of oil to barrels presents problems of measurement errors (Karbuz, 2006; 2004; Mabro, 2001). To deal with these issues, we first convert kilograms of oil imports from each origin/source, into metric tonnes. Then, using the International Table (IT) calorie of energy unit equivalent, we convert the tonnes into barrels of oil. Finally, corresponding barrel unit prices are calculated. As the proposed analysis requires the use of data on international prices of crude oil, we utilise monthly price data on Brent crude oil published in the International Financial Statistics (IFS) of the International Monetary Fund (IMF).

3.2 Diversification index method

For many energy dependent countries, the concept of diversification provides a fundamental framework for ensuring energy import security and dealing with the myriad of risks associated with possible disruptions to production and supply of key energy resources. The principle of diversification of energy resource supplies requires import dependent countries to rely on more than a single producer/supplier. This allows for dependence to be spread across multiple supply sources thereby enhancing energy security through reduced exposure to risks of disruptions in energy markets (Lesbirel, 2004). To assess the extent of South Africa's oil import diversification, we apply the Hirschman-Herfindahl-Agiobenebo (HHA) approach (Agiobenebo, 2000) and derive the diversification index as:

$$I_{div} = \sqrt{\sum_{i}^{N} S_i^2} \tag{1}$$

where I_{div} denotes the diversification index and S_i is the crude oil import share of the i-th country. However, the complex and intertwined nature of risks associated with supply of crude oil imports requires a more rigorous investigation of risks associated with dependence, besides the use of diversification index. The next sections outline the application of portfolio theory to exploring the complex nature of dependence risk.

3.3 Portfolio theory approach to analysing SA crude oil import risks

The modern portfolio theory, developed to assist investors in optimising their portfolios and price risky assets in financial markets, if extended to examining energy import risks serves two crucial functions: (i) as a valuable tool for analysing choices between more or less risky sources of imported

[6] As reported in Trade Statistics data compiled by SARS.

crude supplies, and (ii) assisting policy and other key decision makers in their deliberations about the relationship between diversification and crude oil import risks.

Lesbirel (2004), applying portfolio theory, distinguishes between two main types of risks associated with disruptions to crude oil market, namely, *systematic* and *specific* risks. Systematic risk is defined as the risk affecting relatively large number of suppliers and by extension, a large segment of the global market for crude oil supplies (and production). This makes it quite difficult for oil importers to formulate strategies and measures to ameliorate the effects of such risks. For this reason, systematic risk is often referred to as non-diversifiable risk. Typically, this risk is due to factors such as an unanticipated surge in global demand for crude oil or the collective actions of the major oil producing nations seeking to use oil supplies as a strategic weapon. Such factors can result in higher import prices, and represent a risk to oil importing countries. On the other hand, specific risk (also termed *unsystematic* or *diversifiable* risk) is associated with events or conditions that are more specific to individual or small groups of suppliers rather than the general happenings in international crude oil market. For example, internal political strife or accidents that hinder the productive capacity and limits the export quantity generated by a particular oil producing nation would have implications for oil energy security of countries that rely on such a nation for its crude imports (Wu *et al.* 2007; Lesbirel, 2004).

Two key insights can be gained from understanding these two types of risks. First, in cases where events affecting oil output and its supply to world markets are specific to individual producer nations, the unlikely probability that such events will occur simultaneously implies that a strategy of diversification would have the potential to reduce any adverse effects that might arise from fluctuations of both supply and prices in the oil market. Second, the systematic risk associated with common trends and general movements in the international crude oil represent the 'unavoidable' risk that is left after adopting a diversification strategy. Thus, while diversification could help reduce unsystematic risks, by contrast it cannot lessen risks associated with common movements in world oil markets.[7] On this basis, the relationship between diversification and oil import risks can be empirically formulated in a set of equations.

First, using the price (per barrel) of Brent crude oil as the benchmark for traded price of oil in global markets, the relationship between the variation in South Africa's crude oil import prices and global price of crude oil is expressed as:

$$P_S = \alpha + \beta P_B + \varepsilon \tag{2}$$

where P_S represents the monthly (per barrel) price of South Africa's crude oil imports, P_B denotes monthly prices of Brent crude oil (per barrel).α, β are parameters while ε represents the error term. The parameter β represents a measure of the change in the price of South Africa's oil imports that is associated with a change in world oil prices. To the extent that the parameter is indicative of the sensitivity of oil import prices to common price responses in global oil markets, β provides a quantitative measure of systematic risk. The error term is a measure of specific risk and represents the variation in oil price imports that is unexplained by events in international oil markets. Hence, ε shows the level to which actual oil import prices deviate from predicted values derived from Equation (2).

Next, we examine the risks of individual crude suppliers in South Africa's oil import portfolio and the aggregate risk of the oil import portfolio, using the portfolio risk model given as

$$\sigma^2_{St} = \beta^2 \sigma^2_{P_{Bt}} + \sigma^2_{o\varepsilon_t} \tag{3}$$

where σ^2_{St} is the total risk (variance in crude oil import costs) of South Africa's crude oil imports in year t while $\beta^2 \sigma^2_{P_{Bt}}$ is the measure for non-diversifiable (systematic) risk. $\sigma^2_{o\varepsilon t}$ is the variance of the error term (ε) which provides a measure of diversifiable (non-systematic) risks. Finally, $\sigma^2_{P_{Bt}}$ captures

[7] Using price changes as a measure of risk, Lesbriel (2004) provides a good theoretical outline in explaining how diversification can reduce risks given different co-variances between the costs of imports.

the variance of monthly prices of Brent crude oil in year t. Using Equation (3) the systematic risks associated with South Africa's crude oil import portfolio can be written as:

$$\sigma^2_{PSt} = \sum_{i=1}^{n}\sum_{j=1}^{m} \sigma^2_{P_{Bt}} X^2_{ij}\beta^2 \tag{4}$$

where σ^2_{PSt} is the systematic risk of South Africa's crude oil import portfolio. X_{ij} is the crude oil import from supply origin j in month i and β is the coefficient risk. The terms n and m respectively denote the number of months and the number of countries from which South Africa sources its oil imports. The specific risks of South Africa's oil imports portfolio are expressed as:

$$\sigma^2_{P\varepsilon t} = \sum_{j=1}^{m} x^2_j \sigma^2_{o\varepsilon t} \tag{5}$$

where $\sigma_{P\varepsilon t}$ is the specific risk of South Africa's crude oil import portfolio. x_j is the crude oil import from supply origin j and $\sigma^2_{o\varepsilon t}$ is the specific risk associated with a particular supply source. As the import risks associated with different supply regions are not homogenous, each will contribute differently to South Africa's overall oil import security risk. The significance of each supply source to South Africa's overall oil import risk portfolio can be estimated through incorporating a weighted measure of the risk associated with each supply region, k, into Equation (5). If w_k denotes the risk weight associated with each supply region k, then the specification of South Africa's specific risk in Equation (5) reduces to:

$$\sigma^2_{P\varepsilon t} = \sum_{k=1}^{7} w_k \sigma^2_{o\varepsilon t} \sum_{j=1}^{m} x^2_j \tag{6}$$

The risk weights w_k are obtained using the analytic hierarchy process (AHP). The AHP is essentially a multi-criteria decision approach that employs pairwise comparisons to arrive at a scale of preference among a set of alternatives (Saaty, 1980). Details on the estimation of the risk weights using the AHP are provided in Appendix A.

South Africa's relatively buoyant economic performance since 1994 has coincided with a period of increased demand (in both domestic and international markets) for crude oil and steep increases in the trading price of oil. As a net importer of crude oil, continued growth in South Africa's oil imports will translate into higher values in terms of both quantity imported and the import wage bill. As oil production and reserves are dominated by relatively few countries, the growth in imports will generate higher systematic risks for South Africa's crude oil import portfolio. Equally, the greater the quantity of imports from particular supply sources/regions, the higher the specific risk will be for the country's import portfolio. These factors create substantial difficulties in using Equations (4) and (6) to evaluate the impact of $\sigma^2_{P_{Bt}}$, β and $\sigma^2_{o\varepsilon t}$ on both systematic and specific risks. To improve the evaluation of the impact of $\sigma^2_{P_{Bt}}$, β and $\sigma^2_{o\varepsilon t}$, we substitute the quantity of crude oil imports from each supply region with the corresponding import share (of each supply region) in South Africa's total crude oil imports. This improvement seeks to provide an objective reflection of changes in crude oil import risks. On this basis, the systematic risk index model of South Africa's oil import portfolio outlined in Equation (4) is re-defined as:

$$I_{PST} = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{m} \sigma^2_{PBt} S^2_{ij}\beta^2} \tag{7}$$

where S_{ij} stands for the share of South Africa's crude oil import from supply origin j in the i-th month. Similarly, by rewriting Equation (6), the specific risk index becomes:

$$I_{P\varepsilon_t} = \sqrt{\sum_{k=1}^{6} w_k \sigma^2_{O\varepsilon_t} \sum_{j=1}^{m} s^2_j} \tag{8}$$

where s_j is the share of South Africa's crude oil imports from supply origin j in year t.

4 Empirical Results and Interpretation

4.1 Diversification Index of South Africa's Crude Oil Imports

Based on Equation (1), Figure 5 shows the trend of the calculated diversification index of South Africa's oil imports between 1994 and 2007. A higher index implies more concentration (or less diversification), i.e., South Africa's oil imports are obtained from relatively few suppliers; a lower index, the converse. The diversification index is characterised by three distinct episodes. In the first episode covering the period 1994 to 1998, the diversification index presents a downward trend. Much of this downward trend can be attributed to the end of South Africa's international isolation following the democratic transition of 1994. This resulted in the lifting of all economic sanctions, creating greater access to global trade. With increased participation in global trade and access to more markets, South Africa's supply origins increased from 7 in 1994 to 16 by 1998.[8] This contributed to an increase in South Africa's oil imports, from 55 million barrels in 1994 to over 142 million barrels by 1998. In the second episode covering the period 1999 to 2003, the number of supply origins declined from 12 in 1999 to just 9 by 2002. The decrease in supply sources could be traced to a lower demand for imported oil as South Africa's total oil imports fell by over 30 million barrels when it peaked at just over 110 million barrels in 2002. This period was also marked by a relatively high dependence in the Middle East region as the share of this region in total oil imports by South Africa reached a high of 94.8% in 2000.

The third episode spanning the period 2003 to 2007 coincided with government's implementation of a number of macroeconomic policies aimed at bolstering economic growth and enhancing the delivery of social programmes. Policies related to deepening the country's socio-economic infrastructure have emphasised the role of secure energy supplies in advancing growth and development initiatives. This has prompted government to pay more attention towards diversifying the sources of the country's energy supplies, including crude oil imports (Department of Minerals and Energy, 2006). By 2006, crude oil imports were sourced from 17 different countries resulting in notable reduction in reliance on the Middle East region for oil imports. In 2000, the Middle East region accounted for almost 95% of South Africa's imports. By 2007 this share had declined to 62% as countries in Africa (notably Nigeria, Angola, and Gabon), South America (in particular, Venezuela) and the Russian Federation gradually became important sources of crude oil for South Africa with these three regions accounting for 27.5%, 1% and 5% of South Africa's total imports of crude oil, respectively.

The net effect of these three episodes has been the gradual decrease in South Africa's oil import diversification index with the index reaching its lowest value of 0.68 in 2007. However, the reduction in the diversification index does not necessarily mean a lower oil import risk. Instead, the extent to which import risk is reduced by diversification is dependent on the nature and extent of market and political relationships between supply sources.[9]

[8] These figures reflect South Africa's *major* oil suppliers, where a major oil supplier is one that provides a minimum of 50, 000 barrels of crude oil per year to South Africa.

[9] The case of two sole suppliers operating under two scenarios of positively and negatively co-varying import prices, respectively, serves to illustrate this point. Where import prices co-vary in a perfectly negative manner, an increase in the price levied by one could induce the other supplier to lower its prices in order to raise its market share or strengthen relations with the importing country. In this instance, diversification can reduce import risks significantly. Alternatively, the pursuance of common political and strategic goals could lead to both suppliers operating a well organised cartel that exerts significant influence on production and prices. This arrangement would cause prices of crude oil imports to co-vary in a positive manner. In this case, diversification will increase and not reduce import risk (Lesbirel, 2004).

4.2 South Africa's Crude Oil Import Risks

4.3 *Relationship between South Africa's Oil Import Prices and Global (Brent) Spot Prices*

South Africa's importation of crude oil follows a defined government plan aimed at compensating domestically produced oil energy sources and ensuring that the supply of oil products are not only stable, but available throughout the country at internationally competitive and fair prices (DME, 1998). As a globally traded commodity, crude oil is subject to global prices. It follows that for a net importing country such as South Africa, import prices will track oil prices quoted in the international oil market. Thus, establishing the relationship between South Africa's monthly crude oil imports and the global market price (in this case, the monthly Brent spot price in US dollars) provides an indication of the magnitude of South Africa's crude oil import risk. Figure 6 tracks the trend in monthly prices of South Africa's crude oil imports and the Brent spot price. It indicates that over the period 1994 to 2007, Brent spot prices are generally higher than South Africa's crude import prices with the exception of a sharp increase in South Africa's crude oil import prices between 1996 and 1997. This could be explained by the combined effects of the Asian crises of 1996 to 1997 which led to significant volatility in the exchange rate of the domestic currency (the Rand) and increased imports of crude oil.

Equation (2) provides a quantitative assessment of the relationship between global oil prices and South Africa's crude oil import prices. Owing to the lag of price variations, the error term is auto-correlative. To ensure Equation (2) is adjusted for the error's autocorrelation, we apply the Cochrane-Orcutt method, an approach that yields:

$$P'_{St} = \alpha(1-\rho) + \beta P'_{Bt} + \varepsilon \tag{9}$$

where $P'_{St} = P_{St} - \rho P_{S(t-1)}$, $P'_{Bt} = P_{Bt} - \rho P_{B(t-1)}$and $\rho$is the autocorrelation coefficient of the error series. With parameter estimates given in Table 2, Equation (9) becomes:

$$P_{S(t)} - 0.355P_{S(t-1)} = 0.9654(P_{B(t)} - 0.355P_{B(t-1)}) + 0.731 + \varepsilon \tag{10}$$

The parameter estimates (Table 2) show a strong positive correlation (approximately 0.97) between South Africa's oil import prices and international crude oil prices. This suggests that during periods of supply or production disruptions, the country's import price can be expected to closely track changes in international oil prices.

4.4 *Calculation of South Africa's Crude Oil Import Risks*

Implementing the AHP, we generate the risk weights (Table 3) of the seven regions that supply South Africa with its crude oil imports (see Appendix A for details).

Next, using the absolute values of crude oil imports and calculated risk weights (Table 3), we use the model specifications in Equations (4) and (6) to estimate both the systematic and specific risks of South Africa's crude oil imports. The results as well as estimates of overall risk of South Africa's crude oil imports are shown in Table 4.

Figure 7 highlights the key trends underlying South Africa's oil imports portfolio. Overall risk of the country's crude oil import portfolio displays fluctuating upward trends over the period 1994 to 2007, with notable spikes in 1997 and 2004. With an average share of 62%, specific risk forms the dominant component of South Africa's oil import risk, and shows sharp increases for the period 1994 to 1997. Between 1994 and 1997, South Africa's crude oil imports averaged 18 million tonnes. The largest change in the volume of imports occurred between 1994 and 1997, when oil imports grew from 8 million tonnes to 24 million tonnes, a growth of 195%. In 1994, South Africa's crude oil imports were sourced from only two regions with Middle East accounting for 94% of the country's total oil imports. By 1997, the number of import supply sources had increased from two to six regions resulting in a decline in the diversification index (see Figure 5). However, South Africa remained dependent on imports from the highly volatile markets of the Middle East (79%), Africa (5%) and the Russian Federation (5%). Specific events in major exporting countries of the Middle East and African regions, particularly the United Nations resolution to limit Iraqi oil exports and declaration of a force majeure at export terminals in Nigeria, contributed to a sharp increase in specific risks and the sudden enhancement of South Africa's oil import portfolio in 1997.

Figure 7 also shows that compared to 2003, steep increases in both systematic and specific risks led to a significant increase in the portfolio risk of South Africa's crude oil imports in 2004. The increase in specific risks during this period can be attributed to South Africa obtaining its crude oil imports from only two sources, the Middle East (82.2%) and Africa (17.5%) regions, both of which experienced substantial oil supply disruptions in 2004 (EIA, 2007). In an environment of rising global demand, OPEC's implementation of production cuts and the weather induced disruptions to oil production in the Gulf of Mexico drove increases in the average price of Brent crude oil – from $28 per barrel of oil (/bbl) in 2003 to over $38/bbl in 2004. For South Africa, global trends in world oil prices that prevailed during this period translated into a larger variation in average import prices (from 6.39 in 2003 to 33.25 in 2004). Year 2005 had the highest monthly price variation of 83.83, with imports prices ranging from around $39/bbl in February to $68/bbl in September. Thus, high import prices and greater variations in import prices help explain the high values in the specific and systematic risks in 1997 and the period 2004 to 2005.

The use of large squared absolute values of crude oil imports in the calculation of risks has the effect of overshadowing the impact of fluctuations in international crude oil prices and change in oil import supply sources on the overall import risks of South Africa's import portfolio. To clearly demonstrate the effects of these factors, we calculate the risk index of South Africa's oil import portfolio based on improved measures specified in Equations (7) and (8), respectively.

Figure 8 indicates that from 1994 to 2007, the systematic risk index of South Africa's oil import portfolio was consistently higher than the specific risk index. Three distinct phases underpin the trend in the systematic risk index: the sharp increase in 1999, a declining trend between 1999 and 2003, and the sharp peak of the index in 2005.

The sharp increase in systematic risk between 1998 and 1999 is evidence of the significant increases in international crude oil prices, the impacts of which are not easily avoidable. In an effort to raise oil prices, which fell sharply in late 1997 and remained low through 1998 to early 1999, OPEC and non-OPEC oil producing countries agreed to reduce oil output by a combined 2.104 million bbl/day in early 1999. The lowering of output occurred against the backdrop of increased global demand that was in part fuelled by the recovery of Asian economies from the financial crises of 1997/98. Together, these factors resulted in monthly Brent crude oil prices escalating from $10/bbl in February 1999 to $25.5/bbl by December of the same year. This high variation of 27.59 (see Table 4) in Brent crude prices resulted in the marked increase in the systematic risk index in 1999. In addition, despite the increase in the crude oil prices in 1999, South Africa's oil imports rose from 1.32 million tonnes in January to 2.12 million tonnes in December. This 83.6% growth in imports further contributed to the sharp increase in the systematic risk index for 1999.

The period between 1999 and 2003 was largely dominated by weak oil demand (largely over fears that the September 2001 terrorist attacks could exacerbate the economic recession in the United States thus adversely affecting global economic activity) and substantial increases in oil output of OPEC countries. These events meant that world oil prices which had tripled between January 1999 and September 2000 declined sharply, averaging just over $26/bbl during the period 1999 to 2003. While some increases in oil price occurred at the beginning of 2002 and in mid-2003, there was less fluctuation in oil prices with the variation in the Brent price of crude oil averaging $8.32/bbl during this period. South Africa's imports of crude oil also declined from 19.3 million tonnes in 1999 to 17.2 million tonnes in 2003 (Table 4). Hence, a stable but declining price of oil in global markets coupled with reductions in the volume of oil imports contributed to a lowering of the systematic risks index for the period 2000 to 2003.

Apart from a brief decline in 1998, the specific risk index follows a fairly constant and relatively low increasing trend with two peaks in 1997 and 2005. Despite the increase in supply sources between 1994 and 1997 (from 2 to 6), the Middle East (with a risk weighting of 35%) and Africa (risk weighting of 19%) accounted for over 94% of South Africa's oil imports. This heavy dependence on relatively risky regions contributed to the observed trend of a gradual increase in the specific risk index over the period 1994 to 1997. Between 2000 and 2005, the number of oil supply sources declined to three regions with the average share of the relatively risky regions of Middle East and Africa in total crude oil imports equal to 87 and 12%, respectively. The heavy reliance on both regions translated into a gradual increase in the specific risk index between 1999 and 2005, with the index reaching its highest value of 3.09 in 2005. The largest variance (value of 63.7, Table 4) in international crude oil prices was recorded in 2007. Notably, the average price of Brent crude oil increased from \$54.3/bbl in January to \$77.13/bbl in September of 2007. However, the reduction in crude oil imports (16.06 million tonnes, Table 4) and increased diversification (as supply sources increased to 7 regions) in 2007 contributed to slightly lower systematic and specific risk indices in 2007 compared to 2005.

Figure 9 shows the absence of a linear relationship between the diversification index and specific risk index for the period 1994 to 2007. This highlights the fact that efforts to either reduce or avoid specific risk cannot be achieved by merely increasing the number of crude oil supply sources. Instead, increased crude oil supply sources (diversification) will in effect only reduce specific risk index and consequently the overall portfolio risk if: (a) the right choice of supply regions is identified avoiding economic or political alliances (for example, cartels) and (b) the import shares are well distributed across the different supply sources.

5 Discussion of South Africa's Crude Oil Import Strategy

Since 1994, countries in the Middle East and Africa have, on average, accounted for over 94% of all crude oil imports into South Africa. Given the geo-political and economic dynamics of these two regions, increased reliance on oil producers located in these regions will carry some risks. In seeking to mitigate these risks, policymakers will need to answer some key questions. In particular, how can South Africa adjust crude oil import strategies to reduce import risk? And how much risk can be reduced? To assist in answering these questions, we utilise the risk index model and analyse the changes in the risk index based on four different import strategies/scenarios as follows:

1. Assume that South Africa implements a policy of ensuring that its crude oil imports are the same in each month in year t, and all else is constant. How might such a strategy affect the risk index of the portfolio? The results (see Table 5) indicate that the systematic risk index would decrease by between 0.17 and 7.89%. This explains the strong impact of high international oil prices which raises the systematic risk and thus the high South Africa import risk portfolio.

2. Table 6 shows the changes in the specific risk index if we assume crude oil imports are the same in each region in year t and all else is constant. The results indicate that the reduction in specific risk index would range from 63.10 to 74.45% if South Africa crude oil imports were the same in each year for the period 1994 to 2007. This implies that reducing dependence on high risk regions and increasing supply regions has the effect of lowering South Africa's crude oil import risk.

3. Despite the Middle East having the highest risk weighting among the seven supply regions (34.7%), it accounted for around 83% of South Africa's imports of crude oil over the period 1994 to 2007. How then would the country's specific risk change if we transfer a given percentage of crude oil imports from Middle East to other regions? Table 7 indicates the changes in specific risk due to transfer import strategies based on the assumption that we transfer 10% of oil

imports obtained from the Middle East to other regions without changing the quantity of total imports.

In general, the results (see Table 7) show that such a transfer policy would result in a decrease in the specific risk index, with the magnitude of decrease varying for each region. The largest decrease (of between 8.88% to 9.90%) in specific risk would occur if 10% of crude oil imports were transferred to the region with the least risk weighting - Europe (see Figures 10 and 11). At the other end of the scale, the least reduction in specific risks (ranging from 6.30 to 9.43%) would occur if 10% of Middle Eastern supplies of imports were transferred to suppliers in Africa. The results show that reductions in specific risk index will be greatest if 10% of Middle Eastern imports were to be diversified to Europe, North America, Russia, South America and Africa, in that order. These findings indicate that the lower the risk weight of a region, the greater is the magnitude of the reduction in specific risk if the sourcing of South Africa's oil imports is diversified to that particular region.

4 Real diversification of South Africa's crude imports would mean having same imports from each supply source in every year, assuming all else is constant. If this were the case, Figure 11 shows the impact of such diversification on the specific and systematic risk index of South Africa crude import portfolio for the period 1994 to 2007. With systematic risk usually dependent on events affecting global oil market and prices, having same or constant quantities of monthly crude oil imports would not significantly impact the systematic risk index (see Figure 11).

6 Conclusion

Using portfolio theory, this paper develops an empirical framework that quantifies the security risks associated with South Africa's crude oil imports. The framework begins with the application of portfolio theory to estimating the risks of South Africa's oil imports. Given that international energy geopolitics and policies of oil producers have a bearing on oil import supplies, this builds on the empirical framework by utilising the AHP approach to incorporate these factors into a more robust estimation of oil import risks. The usefulness of both portfolio theory and AHP lies in not only providing for the explicit specification and categorisation of different oil import risks but also, providing a methodology for quantifying the different types of risks and assessing how geopolitical and other policy factors impact on such risks. The chosen methodology is used to derive index models and analyse changes of risks under different import strategies. This, to our knowledge, is the first attempt at applying portfolio theory and AHP methodology in estimating and evaluating oil import risks in the context of an African economy. The results show that episodes of rising (decreasing) international oil prices and/or increases (reductions) in South Africa's oil imports tend to increase (lower) the systematic risks of the country's oil import portfolio. The results also indicate that while diversification of supply sources contributes to a lowering of risks, increased diversification that increases supplies from relatively risky oil producing regions would only serve to enhance the specific risks of South Africa's oil imports.

To assess the impact of diversification and imports adjustments on risk indices, the paper simulates a transfer of 10% of Middle Eastern supplies of oil to other import sources and the maintenance of a constant amount of oil imports per month and region, respectively. Two key findings emanate from these simulations. First, a policy of having the same quantity of oil imported every month or a constant quantity of oil imported from the 7 regions would reduce both systematic and specific risks of South Africa's oil import portfolio. Second, a reduction in specific risks of South Africa's oil imports can be achieved if some of the Middle Eastern supplies can be diversified to less risky regions of Europe, North America and Russia.

The main lesson from these simulation exercises is that South Africa can lower its oil import risks through appropriate diversification and import adjusting strategies. Reducing dependence on countries located in regions with significant geopolitical risks can contribute to lower specific risks.

Most of South Africa's imports of crude oil are carried out by private players linked to the major, locally based energy multinationals that engage in petroleum refining and marketing. To ensure low specific risks, there is a need for a strategic partnerships and cooperation between subsidiaries of the government owned Central Energy Fund (CEF) and private firms in the sourcing of crude oil. In addition, such a framework should aim at fostering bilateral relations with less risky oil suppliers. Ultimately, the framework should lead to a well coordinated system of acquiring oil in the future for purposes of reducing systematic risks that could emanate from exposure to adverse price fluctuations in international oil markets.

While the analysis provides a number of interesting insights into the issue of oil energy security for South Africa, rising demand for energy in the country's transport, manufacturing, construction and commercial sectors implies that any assessment of energy security will benefit from the inclusion of all types of energy resources and supplies.

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Table 1: South Africa's oil self-sufficiency and intensity of oil use: 1994 - 2006

Year	Oil Self Sufficiency	Intensity of Oil Use
1994	-0.52	0.20
1995	-0.51	0.20
1996	-0.51	0.20
1997	-0.52	0.19
1998	-0.53	0.20
1999	-0.58	0.20
2000	-0.56	0.21
2001	-0.54	0.21
2002	-0.56	0.21
2003	-0.59	0.21
2004	-0.54	0.20
2005	-0.56	0.19
2006	-0.60	0.19

Source: Authors' own calculations using data compiled from EIA (2007).

Table 2: Parameter estimates of the relationship between South Africa's crude oil import prices and Brent spot prices[a]

Independent variables	Coefficient	Prob.
Constant	0.7305 (0.8030)	0.4
β	0.9654 (37.739)	0.0
P	0.3587	
Diagnostic tests		
Residual standard error (d.f.)	3.8 (161)	
R-squared	0.9729	
Adjusted R-squared	0.9726	
F-statistic (d.f.)	2895 (2, 161)	
R-square after AR(1) correction	0.9005	
AIC	901.6908	
BIC	910.9720	
Log-likelihood	-447.8454	

Notes: For parameter estimates, figures in parentheses are *t* values. d.f. denotes degrees of freedom.
[a] Dependent variable: South Africa's monthly crude oil import price ($P_{S((t)}$)

Table 3: The risk weight coefficients w_k of South Africa's crude oil import sources

Region	Africa	Europe	Middle East	North America	Russia	South America	Other
w_k	0.192	0.054	0.347	0.101	0.103	0.147	0.057

Table 4: The risks of South Africa's crude oil import for the period 1994-2007

Year	Crude Oil import (million tons)	σ_{Pst} Systematic Risk (a)	σ_{Pet} Specific Risk (b)	Portfolio Risk (a+ b)	σ^2_{Pbt} Brent variance	σ^2_{oet} Error variance	I_{pst} Systematic risk index	I_{pet} Specific risk index
1994	8.087	3.08	5.86	8.93	1.19	1.71	3.18	0.72
1995	17.038	4.19	14.62	18.81	0.82	2.75	2.79	0.86
1996	14.677	8.39	35.69	44.08	4.20	20.60	6.29	2.43
1997	23.864	10.89	67.22	78.11	3.01	35.95	5.05	2.82
1998	21.043	7.25	14.23	21.48	2.24	2.09	4.10	0.68
1999	19.314	25.53	12.62	38.15	27.59	1.57	15.79	0.65
2000	18.320	15.55	17.16	32.71	9.24	2.81	9.62	0.94
2001	18.767	16.16	19.07	35.24	11.01	3.65	10.27	1.02
2002	16.383	11.69	23.57	35.27	8.11	9.38	7.91	1.44
2003	17.167	10.50	22.82	33.32	4.91	6.37	6.68	1.33
2004	23.590	35.21	50.53	85.75	33.14	19.08	16.44	2.14
2005	17.977	27.89	55.56	83.44	38.45	38.15	18.20	3.09
2006	21.579	28.94	22.89	51.83	32.45	6.06	14.88	1.06
2007	16.062	29.89	30.57	60.45	63.72	24.16	17.01	1.90

Table 5: Adjusting crude oil imports every month: The impact on systematic risks

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Real monthly import *Ipst*	3.18	2.79	6.29	5.05	4.10	15.79	9.62	10.27	7.91	6.68	16.44	18.20	14.88	17.01
Average monthly import *Ipst*	3.13	2.67	6.23	4.65	3.98	15.59	9.64	10.03	7.65	6.64	16.16	17.69	14.19	15.81
% contribution	1.56	4.26	0.85	7.89	2.86	1.29	-0.17	2.38	3.17	0.55	1.67	2.79	4.59	7.08

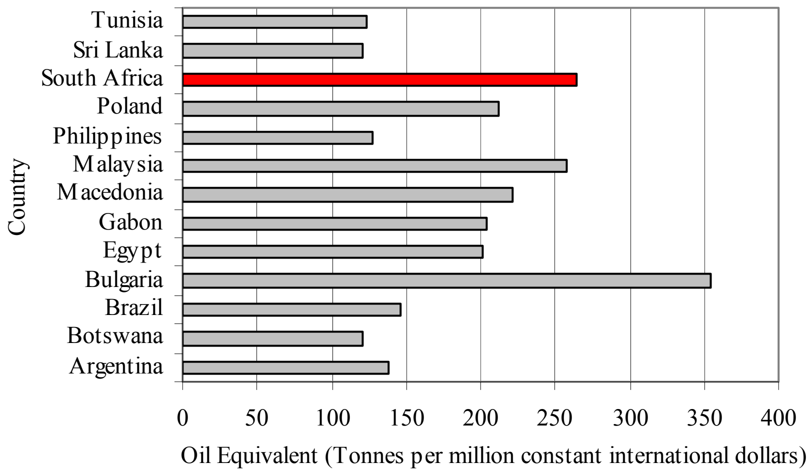
Table 6: Adjusting crude oil imports every month: The impact on specific risks

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Real monthly import *Ipet*	0.72	0.86	2.43	2.82	0.68	0.65	0.94	1.02	1.44	1.33	2.14	3.09	1.061	1.90
Average monthly import *Ipet*	0.19	0.24	0.65	0.86	0.21	0.18	0.24	0.27	0.44	0.36	0.62	0.88	0.35	0.70
% contribution	74.20	74.20	73.34	69.59	69.43	72.64	74.45	73.15	69.59	72.88	70.87	71.45	66.85	63.10

Table 7: Transferring import strategies across different regions: The impact on specific risks

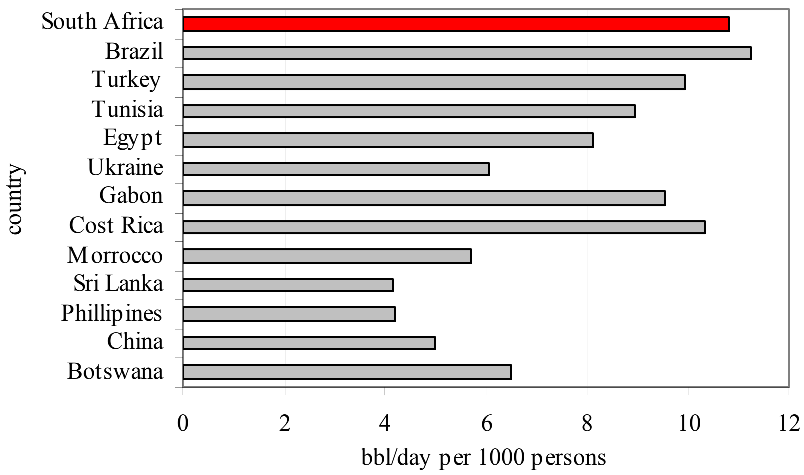
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Real import (*Ipet*)	0.72	0.86	2.43	2.82	0.68	0.65	0.94	1.02	1.44	1.33	2.14	3.09	1.06	1.90
Transfer to Africa (*Ipet*)	0.66	0.78	2.21	2.56	0.61	0.59	0.85	0.92	1.32	1.21	1.97	2.83	0.98	1.78
% contribution	9.43	9.32	9.24	9.22	9.18	9.02	9.35	9.08	8.27	8.90	8.18	8.59	7.85	6.30
Transfer to Europe	0.65	0.77	2.19	2.54	0.61	0.59	0.84	0.92	1.30	1.20	1.94	2.79	0.96	1.73
% contribution	9.43	9.82	9.88	9.69	9.85	9.85	9.90	9.86	9.65	9.83	9.66	9.77	9.53	8.88
Transfer to North America	0.65	0.77	2.19	2.54	0.61	0.59	0.84	0.92	1.30	1.20	1.94	2.79	0.96	1.74
% contribution	9.43	9.81	9.81	9.68	9.56	9.73	9.82	9.79	9.61	9.76	9.58	9.69	9.46	8.81
Transfer to Russia	0.65	0.77	2.19	2.55	0.61	0.59	0.84	0.92	1.30	1.20	1.94	2.79	0.96	1.74
% contribution	9.43	9.81	9.81	9.60	9.74	9.76	9.82	9.79	9.52	9.76	9.58	9.69	9.43	8.58
Transfer to South America	0.65	0.77	2.19	2.54	0.61	0.59	0.85	0.92	1.30	1.20	1.94	2.79	0.96	1.74
% contribution	9.43	9.74	9.74	9.71	9.56	9.71	9.75	9.72	9.54	9.69	9.51	9.62	9.36	8.68
Transfer to Other	0.65	0.77	2.19	2.54	0.61	0.59	0.84	0.92	1.30	1.20	1.94	2.79	0.96	1.74
% contribution	9.43	9.81	9.82	9.85	9.71	9.83	9.89	9.83	9.64	9.82	9.65	9.72	9.31	8.77

Figure 1: Energy intensity for selected middle-income countries in 2003[1]



Source: World Resources Institute – Earthtrends Database (2007).

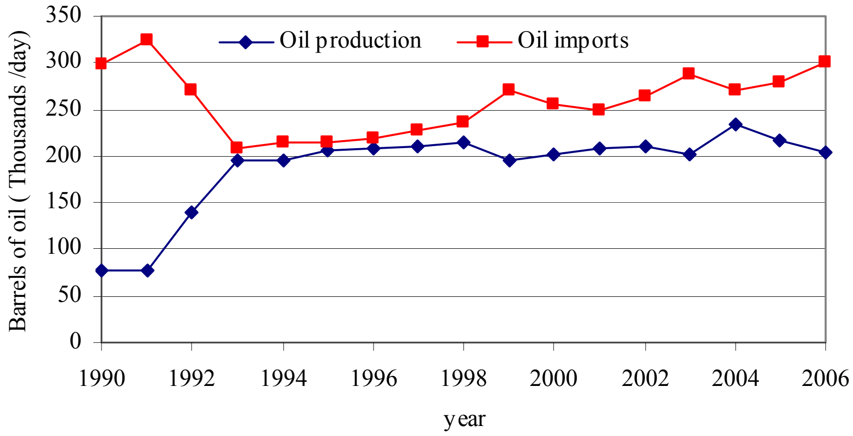
Figure 2: *Per capita* oil consumption for selected middle-income countries in 2007



Source: Central Intelligence Agency (2007).
Note: This measure is based on total oil consumed in barrels per day (bbl/day). The discrepancy between the amount of oil produced and/or imported and the amount consumed and/or exported is due to omission of stock changes, refinery gains and other factors.

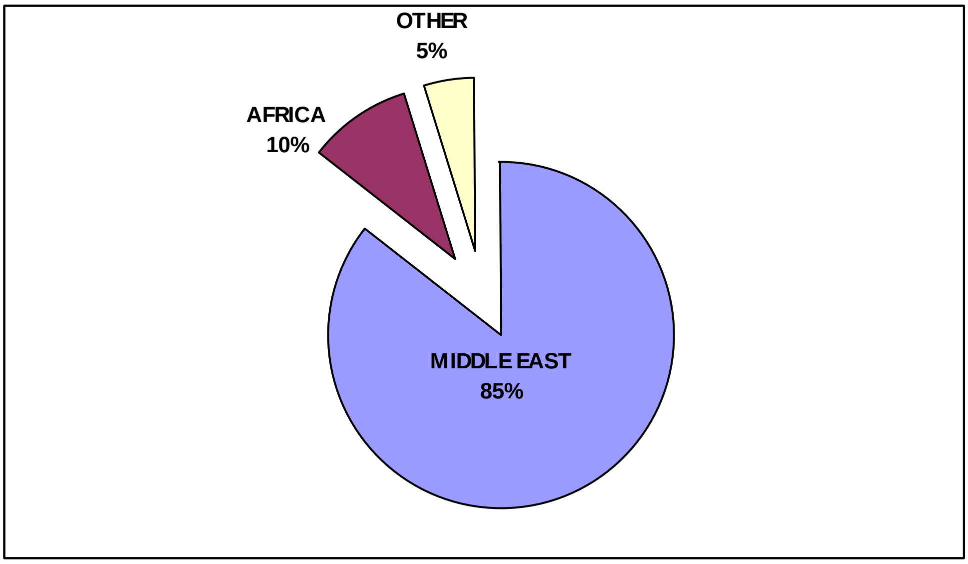
[1] Energy intensity is calculated as the ratio of a country's total energy consumption to GDP. It reflects the primary amount of energy used per unit of income generated by a country's economy. The primary amount of energy includes coal and coal products, oil and petroleum products, natural gas, nuclear power, hydroelectric power and biofuels. Using purchasing power parity (PPP) rates, GDP is converted to international dollars and rescaled to 2000 to give a common reference year (World Resources Institute, 2007).

Figure 3: South Africa's oil production and imports: 1994 – 2006



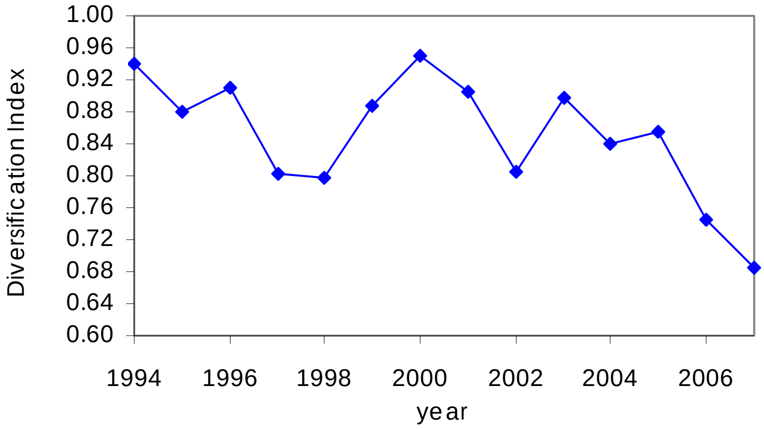
Source: BP (2007).

Figure 4: South Africa's crude oil imports by region – average share, 1994 – 2006



Source: Authors' own calculations based on Trade Statistics of SARS (2007).
Note: The terms Middle East, Africa and Other are collective names of the geographical location of South Africa's major oil supplying partners. The Middle East covers the following countries: Iran, Saudi Arabia, Kuwait, United Arab Emirates Yemen, Iraq, Oman and Qatar. The African region comprises Nigeria, Angola, Gabon and Cameroon. The term "other" includes countries such as the Russian Federation, Venezuela, Mexico, Libya and the United Kingdom.

Figure 5: Diversification index of South Africa's crude oil imports: 1994 – 2007



Source: Authors' Own Calculations.

Figure 6: Trend in South African monthly crude oil import prices and the monthly Brent spot prices: 1994-2007

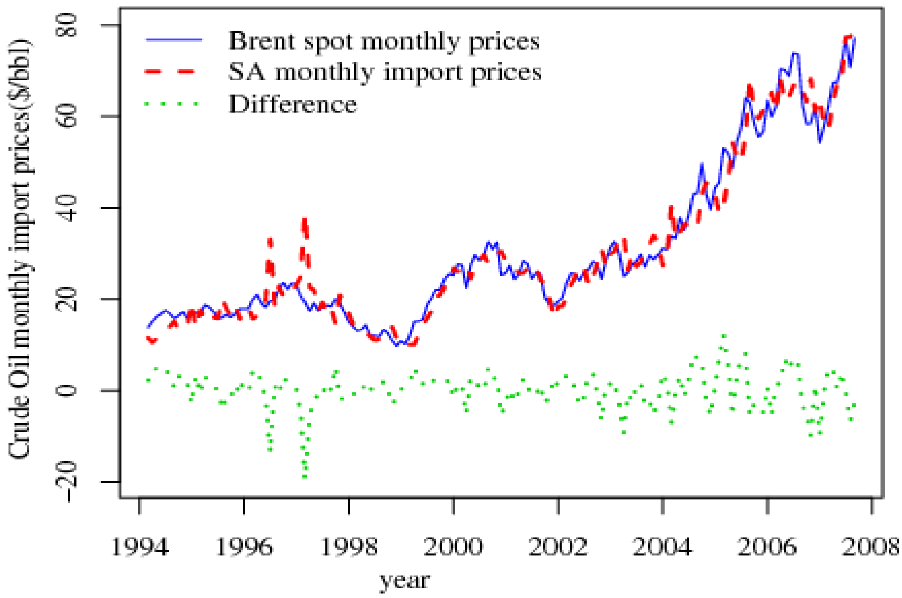


Figure 7: The systematic risk, specific risk and the total portfolio risk for South Africa's crude oil imports for the period 1994 - 2007

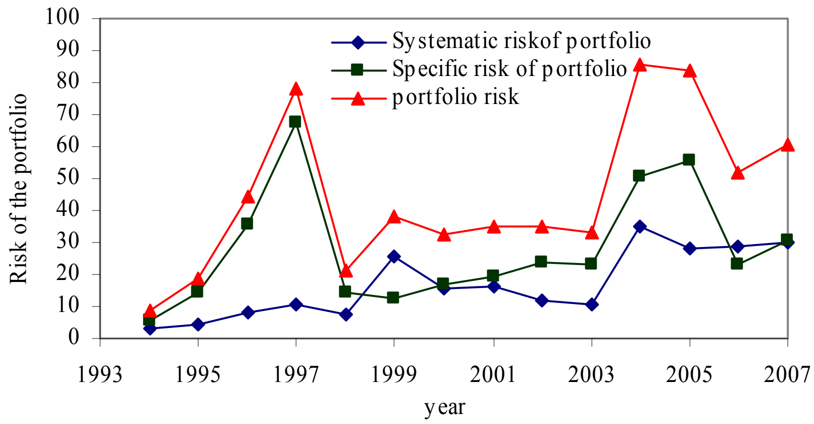


Figure 8: The systematic and specific risk index of South Africa's crude oil imports for the period 1994 - 2007

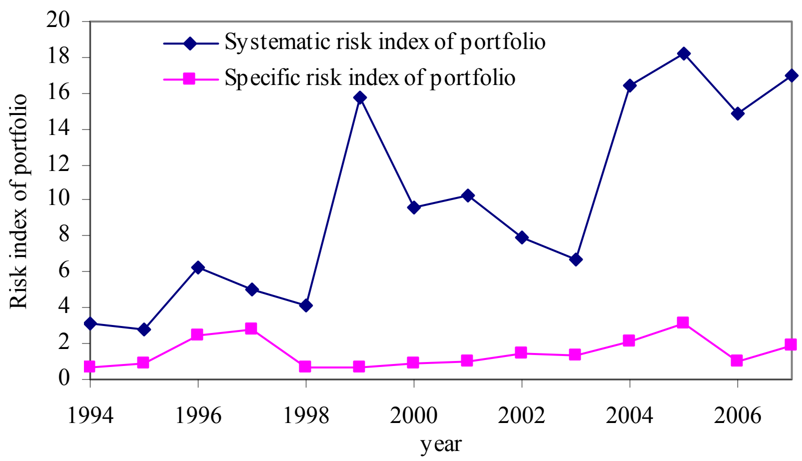


Figure 9: The relationship between the diversification index and the specific risk index of the portfolio for South Africa crude oil imports for the period 1994-2007

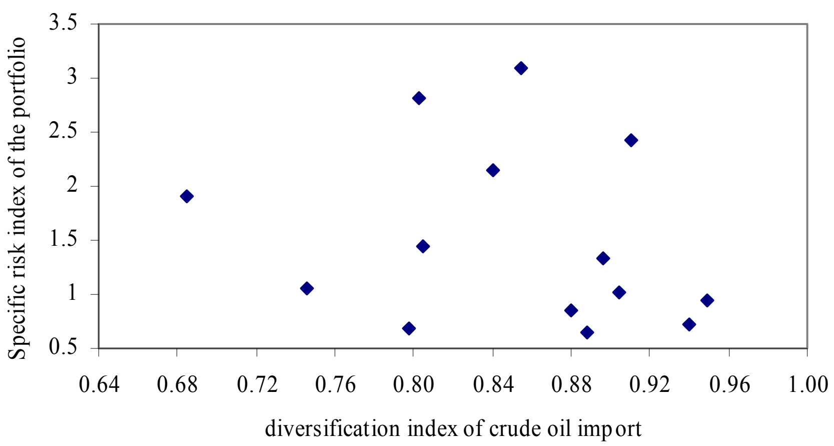


Figure 10: The change in risk index based on transferring import strategies for the period 1994-2007

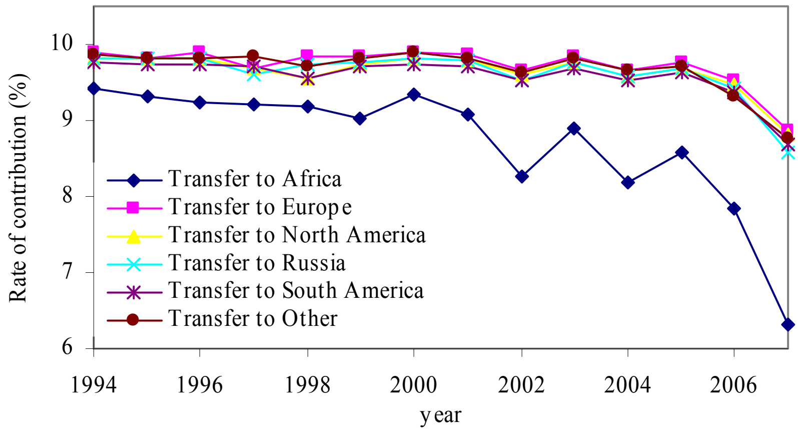
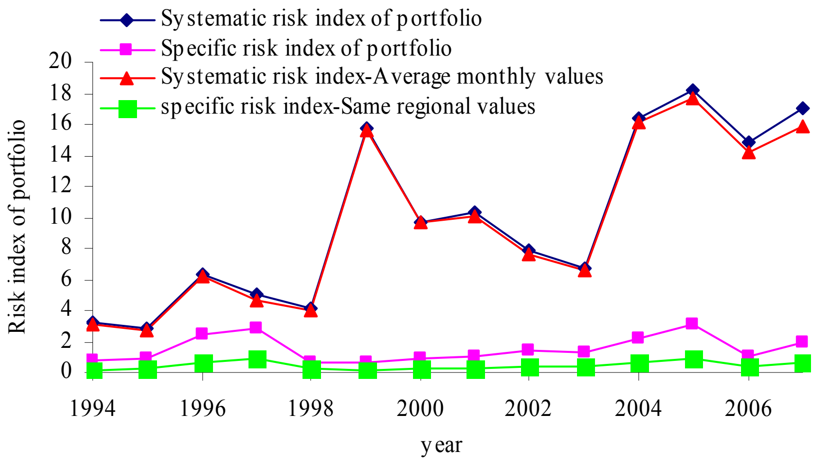


Figure 11: The changes in risk index due to different strategy adjustments in South Africa's Crude oil imports for the period 1994-2007



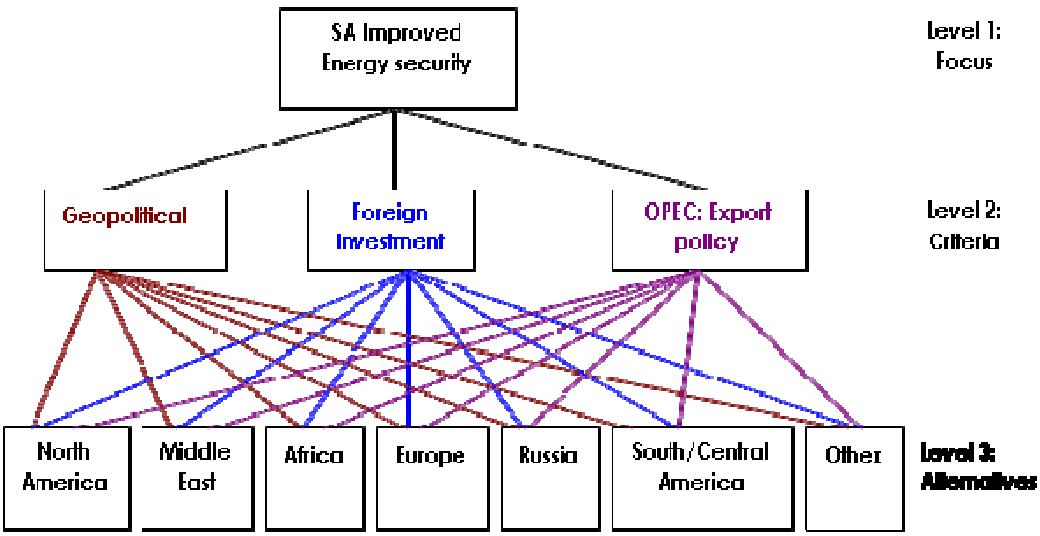
APPENDIX A

Application of the Analytical Hierarchical Process (AHP) in deriving the Import Risk Weights for South Africa's Crude Oil Suppliers

AHP has been used in a wide variety of complex decision-making problems, such as the strategic planning of organisational resources (Saaty, 1994), the evaluation of strategic alternatives (Yang and Lee, 1997), and the justification of new manufacturing technology (Albayrakoglu, 1996). The first step of the AHP process is to develop a decision hierarchy model that evaluates the decision-making problem on the basis of the components of the problem, namely: (i) the goal or focus, (ii) objectives or criteria, and (iii) the alternatives.

For the goal of achieving improved South Africa's crude oil imports security risk, the strategy is to diversify the crude imports among a list of identified supply regions (termed alternatives), where the diversification strategy is based on how well the alternatives rate against a chosen set of criteria or objectives. These objectives include: (a) *geopolitical factors* (such as the potential for supply sources in certain regions to suffer from militant attacks, external invasion, civil unrest, strikes, and tense relations with oil trading partners); (b) *investment policies* governing the oil sector of the supply country (for example prohibition of foreign investment or the nationalisation of oil resources); and (c) *export policy* of supply nations (such as being members of OPEC). Figure A1 outlines a hierarchical ranking of these different criteria and how they interact. The criteria are weighted in terms of importance to the decision maker with the overall "score" of an alternative measured as the weighted sum of its rating against each criterion (objective).

Figure A1: A Decision hierarchy model for selecting South Africa's Crude Oil Imports Supply Sources in enhancing Oil Import Energy Security Risk



To allow for decision makers' uncertainties, Saaty (1980) utilises a scale of values that allows the qualitative judgments of comparison to be translated into quantitative terms (see Table A1). This scale of relative importance covers an interval of values between 1 (equal importance of aspects) and 9 (extreme importance of one over the other). The reciprocal values of the precedents are also defined so that if, for example, a preference intensity of 3 is assigned to an aspect compared to another aspect, then the latter has a preference intensity that is the inverse of the first (1/3) (see Table A1).

Table A1: Scale of Comparative Judgment and the Numerical Equivalent

Definition	Intensity
Absolutely the most important	9
Much more important	7
More Important	5
Slightly more important	3
Equal Importance	1
Slightly less important	1/3
Less Important	1/5
Much less Important	1/7
Absolutely less Important	1/9

Source: Saaty (1980).
Note: Intermediate values 2,4,6,8 are used to represent compromise between preferences.

To determine the relative importance (weights) of each criterion (i.e., geopolitical, investment and OPEC memberships) to the total crude oil import risk in South Africa, we design a pairwise comparison matrix, (Table A2), with each criteria weighted in terms of its relative importance to the decision maker.

Table A2: Sample Pairwise Comparison Matrix (A) for the criteria in terms of importance to decision makers' Judgment

Criteria	Geopolitical	Investment	OPEC
Geopolitical*(g)*	**1**	**3**	**7**
Investment***(l)***	1/3	1	5
OPEC***(o)***	1/7	1/5	1

An intensity of 3 implies that geopolitical factors have slightly more important impact on crude oil import risks than foreign investment policies, and has a much more important impact (intensity of 7) when compared to OPEC Membership of supply regions. To obtain criteria weights, we use the Eigen-vector method $(Aw=\lambda w)$, where A represents the comparison matrix (Table A2), $w = (g, l, o)$ is the criteria weights vector (normalized to sum to 1) and λ is the maximum Eigen value, approximately equal to 3. A consistency ratio that indicates whether or not there are significant contradictions in the pairwise comparison values is also calculated. The consistency ratio should be less than or equal to 0.10 to accept the calculated weights. If the consistency ratio is greater than 0.10, the decision maker is inconsistent in making comparative judgments among the criteria and has to derive another set of pairwise comparison values.

Next, for each criterion, we define a matrix of pairwise comparison values of the alternative suppliers relative to their importance to criteria. For example, Table A3 shows the pairwise comparison values of supply sources in terms of importance to geopolitical factors. Similar pairwise comparison values are generated for criteria of foreign investment and OPEC membership.

Table A3: Sample Pairwise Comparison Matrix for the supply regions in terms of importance to geopolitical factors

	Middle	North	South

	Africa	Europe	east	America	Others	Russia	America
Africa (g_A)	1	4	1/2	4	4	3	2
Europe (g_E)	1/4	1	1/5	1	1	1/2	1/3
Middle east (g_M)	**2**	**5**	**1**	**5**	**5**	**4**	**3**
North America(g_N)	1/4	1	1/5	1	1	1/2	1/3
Others(g_O)	1/4	1	1/5	1	1	1/2	1/3
Russia(g_R)	1/3	2	1/4	2	2	1	1/2
South America (g_S)	1/2	3	1/3	3	3	2	1

In relation to geopolitical criteria (Table A3), **Middle East (g_M)** is rated more important (intensity of 5) compared to Europe, North America and Others; slightly more important (intensity of 3) than South America, and almost of equal importance (intensity of 2) with Africa. Geopolitical related weights for supply regions are then obtained by applying the Eigen-vector method: $(Ag=\lambda g)$, where A represents the pairwise comparison matrix (Table A3), $g = (g_A, g_E, g_M, g_N, g_O, g_R, g_S)$ is the weights vector and λ is the maximum Eigen value, which should be approximately equal to 7. If the calculated consistence index is beyond 0.10, then the decision maker is not consistent in his comparisons and has to design a more consistent pairwise comparison matrix. Similarly, *investment related weights:* $l = (l_A, l_E, l_M, l_N, l_O, l_R, l_S)$ and *export policy* (OPEC membership) related *weights* $o = (o_A, o_E, o_M, o_N, o_O, o_R, o_S)$ are generated.

Lastly, the overall "score" of each alternative supplier source is calculated as the weighted sum of its rating against each criterion (objective). For example, the overall score or risk incurred by sourcing crude oil from Africa equals $(g_A*g) + (l_A*l) + (o_A*o)$ (see Table A4).

Table A4: Calculation of Crude oil Supply Source Risk Weights

	Geopolitical	Investment	OPEC	Regions' Risk weights
Criteria Weights	g	l	o	
Supply Source				
Africa	g_A	l_A	o_A	$(g_A*g) + (l_A*l) + (o_A*o)$
Europe	g_E	l_E	o_E	$(g_E*g) + (l_E*l) + (o_E*o)$
Middle east	g_M	l_M	o_M	$(g_M*g) + (l_M*l) + (o_M*o)$
North America	g_N	l_N	o_N	$(g_N*g) + (l_N*l) + (o_N*o)$
Others	g_O	l_O	o_O	$(g_O*g) + (l_O*l) + (o_O*o)$
Russia	g_R	l_R	o_R	$(g_R*g) + (l_R*l) + (o_R*o)$
South America	g_S	l_S	o_S	$(g_S*g) + (l_S*l) + (o_S*o)$