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Energy Security and Portfolio Diversification:

The Exporter's Perspective

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Key Points

Exporters' perspectives play an important but overlooked role in the energy security domain. This study aims to improve the understanding of this domain by highlighting relevant challenges, indicators and policies. We apply the portfolio theory approach, using historical oil export 'mirror' data of five Gulf Cooperation Council (GCC) countries to construct two portfolios for each that represent the trade-offs between maximizing returns (oil export growth or export prices) and minimizing risks, represented by the standard deviation of return variables. We further assess the resilience of the portfolios to external demand and logistical shocks by running several disruptive scenarios. We find that:

The structure of an oil export portfolio, i.e., the shares of exports associated with specific oil importers, has a significant impact on the risk levels associated with export growth and average export prices of oil.

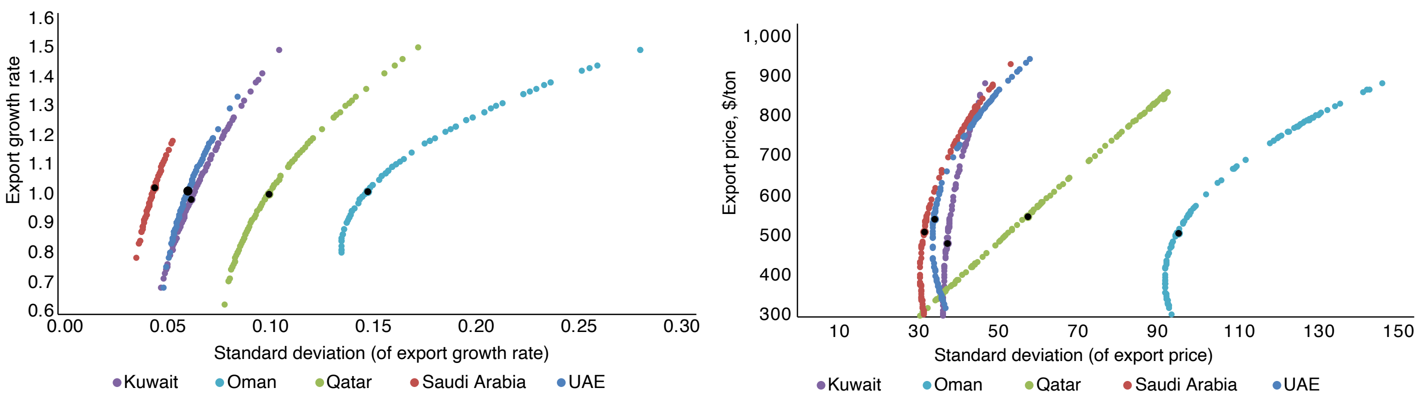
Oil exporters covered in this study tend to adopt a balanced approach to the risks associated with export volume growth and pricing (see figure below), unlike some major oil importers that tend to prioritize either the physical supply or price component of energy security.

Increasing oil exports to China would improve portfolio performance for Saudi Arabia and the UAE, but not for Kuwait and, especially, Oman, due to increased volatility.

Reduced oil exports to the United States, if compensated by demand elsewhere, would have a significant impact only on Kuwait and Saudi Arabia. Such rebalancing slightly increases average export prices for both countries, and reduces the volatility of Saudi Arabia's export growth and of Kuwait's export prices.

A blockade of the Malacca Strait would reduce export volumes and increase portfolio risks for all five economies, with Kuwait and Oman most affected.

Figure. Efficient oil export frontiers: export growth rate and export price.



Source: KAPSARC research.

Note: Black dots represent average monthly values observed in 2018.

Summary

Despite the increasing attention paid to energy security and the continuously broadening scope of the field, the perspective of energy-importing countries (i.e., supply security) has overshadowed that of exporters, who seek to ensure demand security. As official statements and policy documents illustrate, major energy exporters and relevant international organizations realize the significance of energy demand security for their economies and global markets. However, with a few exceptions — most notably, Russia and Iran, where external pressure catalyzed the development of energy/demand security strategies — energy exporters have not fully embedded the concept into their national and global energy policy and security agendas.

The inclusion of exporters' viewpoints also allows a more comprehensive methodological approach to energy security research. Energy exporting and importing economies face many of the same challenges and threats to their energy security, primarily issues related to domestic energy systems, physical security, and logistics. However, energy exporters face a separate range of economic challenges. These include global and regional macroeconomic concerns, global market instability, increasing competition from emerging producers and substitutes, protectionist policies, and sanctions, among others. Some of the risks can be diversified across buyers, supply channels, fuels, and geographies; however, others are systemic, as demonstrated by the COVID-19 pandemic and subsequent plunge in global oil demand.

Specific energy security risks encountered by exporters require an applicable measurement framework, especially in the foreign trade domain. For instance, while import dependency can be assessed as a volume- or value-based proportion of imported energy to energy balance, total imports, or gross domestic product (GDP), export dependency can be quantified as the share of exports to total energy production, total final consumption, total exports, trade balance, or GDP. Other energy security indicators, such as those assessing diversification levels, reliability of contractors, and transit routes, apply to both exporters and importers.

These challenges can be mitigated via policy measures that target either the domestic market or foreign trade. Fiscal incentives, government and public-private investments, and energy demand management, among other policies, can contribute to energy security and generate additional energy export flows. For energy exporters, diversification — particularly of buyers, energy and fuel types, shipping routes and modes — remains a critical energy security tool. Additional demand security strategies include vertical integration across global energy value chains, managing payment and shipping terms of export contracts, and various risk hedging instruments, including financial derivatives and bilateral hedging agreements.

This study showcases how portfolio theory can be used to assess and manage energy security from the exporter's perspective. Using historical oil export 'mirror' data for five Gulf Cooperation Council (GCC) countries, we construct two portfolios for each to represent the trade-offs between maximizing returns (oil export volume growth or export prices, the two key aspects of energy demand security) and minimizing risks represented by the standard deviation of return variables.

We find that the structure of a country's energy export portfolio — along with its diversification levels, total export volumes and growth patterns — has a significant impact on the returns and risk levels associated with its

oil exports. A balanced export portfolio not only reduces the potential impacts of risks associated with specific import markets, but can also alleviate the consequences of systemic risks.

Among the countries in focus, Saudi Arabia has composed the most efficient oil export portfolio with an emphasis on securing export volume growth, closely followed by Kuwait and the UAE. Qatar and Oman have less optimal portfolio structures and risk profiles.

We also test the derived portfolios for resilience to external demand and logistics shocks by running three counterfactual scenarios — increased Chinese demand, export redistribution and Malacca Strait blockade — and comparing the outputs with the 2018 baseline values.

> A sharp increase in exports to China would improve the oil export portfolio risk profiles for Saudi Arabia and the UAE, but increase volatility for Kuwait and, especially, Oman.

> A reduction of oil exports to the United States would have a significant impact only for Kuwait and Saudi Arabia. However, if this were offset by increased demand from other regions, it would improve, although insignificantly, average export prices for both countries and reduce the standard deviation levels of export growth (for Saudi Arabia) and of export prices (for Kuwait).

> Closure of the Malacca Strait would impact all GCC oil exporters, both in terms of reduced export volumes and portfolio risks, highlighting the necessity of diversifying not just across buyers, but also demand regions, as well as supply routes and modes. Kuwait and Oman would be the worst affected by the disruption.

The portfolio theory approach serves as a useful tool for analyzing energy security issues of exporting countries. Its potential applicability extends beyond the scope of this study to areas such as the assessment of more complex portfolios comprising various export fuels and supply chains (i.e., combinations of buyers and various delivery modes and/or routes). However, further development of other energy demand and export policy tools, indicators, and analysis frameworks remains essential for improving the performance of energy-exporting economies and advancing the study of energy security in general.

Energy Security From the Exporter's Viewpoint

Expanding the conventional energy security scope

Energy security has long been a core element of energy policy and national security. Initially, the concept of energy security was confined to "assuring sufficient energy supplies" (Willrich 1976), reflecting the crucial role of energy in World War I and II and the aftermath of the energy crises in the 1970s. In the subsequent decades, especially after the oil price shock caused by the Gulf War, the economic aspects of energy security, primarily the affordability of energy and its impact on the national welfare, became focal points.

Numerous recent studies suggest that the energy security paradigm be expanded to address other issues. These include infrastructure, environmental and societal impacts, energy efficiency, and governance, among others (see Galkin, Bollino, and Bigerna [2019] for a detailed review of relevant literature). However, the security of physical supply and price affordability remain the main pillars of energy security, as evidenced by the definitions of this concept adapted by international organizations, such as the International Energy Agency,[1] the United Nations,[2] and the EU.[3]

Energy security has been primarily viewed from the consumer's (or importer's) perspective. The predominant body of literature on the subject has been produced in the energy-importing economies and tends to employ language that reflects this bias. Formal definitions of energy security and relevant policy documents often refer to the security of 'supply' rather than the more neutral 'energy,' and describe prices using words such as 'affordable' rather than 'fair,' 'reasonable,' or 'stable,' which would also reflect the energy producer's / exporter's interests.

While the physical security and stable flow of energy supplies affect both importers and exporters, their approaches to the economic component of energy security obviously differ. Energy exporters are also vulnerable to oil price shocks, such as those of 1986, 1998, and 2009, which led to a significant decrease in revenue. During such periods, energy exporters become increasingly concerned with the security of demand. This may lead to insufficient investment, particularly in the upstream sector, amplifying the magnitude of energy price cycles and their destabilizing impact on global energy markets.

Unlike their demand / import-focused counterparts, the international organizations for energy exporters do not present a clear definition of energy security in their key policy documents. The official OPEC statute (2012) does not explicitly mention the term 'energy security' but identifies goals that reflect the underlying concept of security of demand for energy exporters: "…the necessity of securing a steady income to the producing countries; an efficient, economic and regular supply of petroleum to consuming nations; and a fair return on their capital to those investing in the petroleum industry." Further, various OPEC press releases on the issue emphasize "predictable demand and stable prices" and "security of demand" (OPEC 2008), "the reciprocal nature of energy security" (OPEC 2006b) and "minimisation of market uncertainties" (OPEC 2006a).

The Gas Exporting Countries Forum (GECF) cites contributing to global energy security as part of the organization's mission, and lists "supporting the security of supply and demand" among its key initiatives. (GECF 2017). GECF also emphasizes "visibility of revenues," transparent "market mechanisms" and "policy actions," along with the absence of "politically motivated restrictions and unilateral decisions and interventions" as the factors that contribute to both security of supply and demand (GECF 2015, 2018).

Among the major energy-exporting countries, Russia demonstrates the most elaborate policy approach to energy security, and security of demand in particular. The Russian Federation's newly adopted doctrine of energy security (Minenergo 2019) defines energy security as the condition where the nation's economy and population are protected from the national security threats in the energy domain, where the consumers are supplied with fuels and energy in accordance with the requirements specified in the legislation of the Russian Federation, and where the export contracts and the international obligations of the Russian Federation are fulfilled. The doctrine also identifies major energy security challenges and threats. It classifies those related to foreign trade and relations into three subcategories: economic (e.g., shifts and slowdown of global economic growth, increasing the resource base, new emerging exporters, contraction of existing markets, and access to new ones), political (changes in international regulations, policy discrimination, sanctions and transit security) and military.

Although Iran has published no policy document specifically dedicated to energy security, references to the subject can be found in a broad range of legislation and official rhetoric including the Iranian Petroleum Act of 1987 and its amendments, the country's five-year development plans, the regulations that define the functions of the Ministry of Petroleum, and the general policies of the 'Resistance Economy' espoused by Ayatollah Khamenei (Aminzadeh and Khodaparast 2019). These sources identify four key themes within the energy security domain. (1) *Economic security* relates to stable or increasing prices and energy demand, primarily in the global energy market. (2) *The absence of energy sanctions* focuses on monitoring existing and potential sanctions and developing mitigation plans. (3) *Physical security* seeks to protect energy facilities and transit routes from military and piracy attacks. (4) *Environmental security* primarily aims to prevent and mitigate the environmental impact of oil and gas exploration, development, extraction and production.

Not all energy-exporting nations emphasize foreign trade in their energy security strategies. Moreover, some countries devote relatively little attention to energy security compared with other aspects of their energy policy agendas. The National Energy Security Assessment of Australia, which has not been updated since 2011, defines energy security as the "adequate, reliable and competitive supply of energy to support the functioning of the economy and social development" (Department of Resources, Energy and Tourism 2011). The document never explicitly mentions the security of demand or revenue with regard to exports. Instead, it focuses on the security of fuel imports, acknowledging that, compared with electricity and natural gas, liquid fuels depend more on international supply chains and global market conditions than domestic policy decisions. Canada exhibits a similar approach to energy security. The Energy Safety and Security Act (Ministry of Natural Resources 2016) focuses on domestic operational and infrastructure issues. Policy debates in the energy security domain generally revolve around the domestic problems of infrastructure connectivity, countercyclical investment, and energy intensity.

In Nigeria, despite the dominant share of petroleum in total exports and gross domestic product (GDP), energy security policies also prioritize domestic issues. Major policy documents, including the National Energy Policy (Energy Commission of Nigeria 2018) and National Energy Masterplan (Energy Commission of Nigeria 2014), do not articulate the concept of energy security, but highlight measures that would contribute to its enhancement, including diversification of the energy mix, increasing the reliability of energy systems, building up domestic capacities, improving energy efficiency, and increasing research and development in the energy domain.

Classification of energy security threats

The two major categories of energy security threats — physical supply disruption (such as armed conflict, piracy, terrorism, expropriation, and natural disasters) and economic (volume and price) instability — apply to both importers and exporters. However, exporters face a distinct set of challenges that require specific risk mitigation strategies. These include:

- Negative macroeconomic dynamics (globally, and in importing economies)
- Slowing demand for energy and specific fuels (globally, and in importing economies)
- Downside price fluctuations in the global markets
- Increasing competition, including from new exporters
- Buyer-related risks including breach of contract and default
- Protectionism, including tariff and non-tariff market access barriers
- Sanctions, ranging from export embargoes to technological, financial, investment and other collaboration restrictions
- Shifts in legislation in energy-importing markets

These risks can be further classified by fuel type and geography. The potential geographic breakdown can distinguish between domestic and international markets (by individual countries or combinations of countries/regions), as well as transit areas. Such classification can inform prevention and mitigation strategies by differentiating between diversifiable and non-diversifiable (systemic) risks.

Measuring energy security

Most energy security indicators apply to both energy importing and exporting countries. These "universal" indicators generally measure the quality or status of a domestic energy system, such as its reliability, resilience, availability and diversity of resources, investment flows, and environmental impacts. However, in the areas related to foreign trade, indicators and their interpretation differ significantly between energy importers and exporters; these can be broadly divided into three categories: dependency, markets and supply chains, and trade strategies.

A country's energy trade balance is a primary indicator and source of data for dependency, often expressed in physical units such as barrels of oil or tonnes of oil equivalent. Net energy exports generally imply a certain self-sufficiency level — one of the most basic conventional energy security indicators. However, in the case of energy, exporters' dependency can also be interpreted as the level of exposure of the energy sector to international markets. Moreover, despite overall net energy exports, a country may have net dependency for particular fuels. Table 1 compares aggregated net energy exports with energy production and total final consumption (TFEC) for the Gulf Cooperation Council (GCC) states.

Table 1. Relative share of net energy exports to energy production and TFEC for GCC countries, 2017.

Country	Energy production (Mtoe)	TFEC (Mtoe)	Net exports (Mtoe)	Net exports, % energy production	Net exports, % TFEC
Bahrain	22.4	6.3	8.3	37%	132%
Kuwait	162.2	19.3	128.3	79%	665%
Oman	77.9	21.3	50.1	64%	235%
Qatar	225.2	18.3	179.5	80%	981%
Saudi Arabia	646.8	140.7	425.4	66%	302%
UAE	229.4	140.7	136.9	60%	97%

Source: IEA 2019.
Note: MTOE = million tonnes of oil equivalent; TFEC = total final consumption.

The indicators measuring the economic dependency (and potential vulnerability) of an energy-exporting nation generally compare the export values for energy (or a particular fuel) with major macroeconomic indicators. Dike (2013) suggests total exports and GDP as the key measurements (see Table 2 for the corresponding estimates for the GCC countries). However, one can also estimate the impact of energy exports on a country's trade balance, current account, and total sales (or value added) of the energy sector.

In the energy security literature, the conventional approach for energy importers to assess the risk profiles of suppliers involves using a variety of measurements and indicators. Similarly, energy exporters can develop risk assessment toolkits for existing and potential markets or specific buyers that evaluate political and economic risk indices, bilateral trade and payment history, current and potential trade barriers, other protectionist measures, and domestic policies that would impact energy exports. The risk factors for specific energy export routes and modes (e.g., maritime shipments, pipelines, and railways) can also be quantified and combined with consumer risk profiles for a comprehensive energy security analysis of export supply chains.

The other group of energy demand security indicators focuses on a country's export portfolio and strategies. The Herfindahl-Hirschman Index (HHI) is a common measure of market concentration used to determine market competitiveness and can be used to analyze the diversification of energy exports. Figure 1 shows the historical trends in HHI index for the five GCC countries. According to the United States (U.S.) Department of Justice (2018), HHI measurements below 1,500 indicate a competitive market, from 1,500 to 2,500 a moderately concentrated market, and above 2,500 a highly concentrated market.

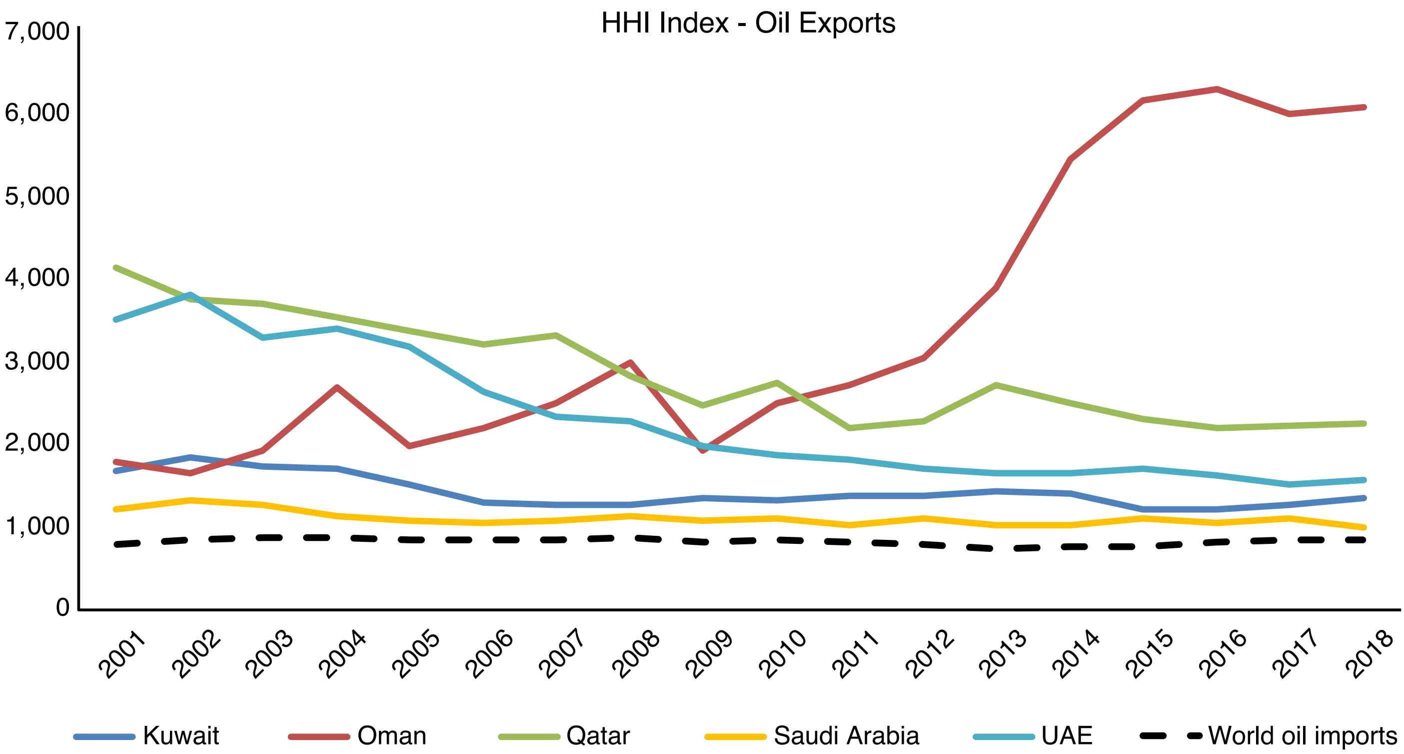
Table 2. Contribution of mineral fuel* exports to total exports and GDP for GCC countries.

Country	Exports of mineral fuels, US$ million		Total exports, US$ million		GDP, US$ million		Exports of mineral fuels / total exports, %		Exports of mineral fuels / GDP, %	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Bahrain	5,564	6,921	11,088	12,979	35,305	37,740	50%	53%	16%	18%
Kuwait	49,573	65,391	52,977	71,941	120,449	139,742	94%	91%	41%	47%
Oman	18,655	27,323	32,404	43,281	70,577	79,253	58%	63%	26%	34%
Qatar	54,351	72,509	63,968	81,571	166,929	192,009	85%	89%	33%	38%
Saudi Arabia	170,245	231,587	213,210	285,847	686,549	779,167	80%	81%	25%	30%
UAE	69,182	92,538	313,510	316,860	377,701	414,179	22%	29%	18%	22%

Sources: World Bank 2019, ITC 2019, CEIC 2019.

*Classified under HS Code line 27.

Figure 1. HHI oil export indices for GCC countries.



Sources: ITC 2019, KAPSARC calculations.

Diversification of an energy export portfolio generally improves its risk profile. However, it may also increase costs due to the higher overhead associated with managing additional consumers/markets and reduce the share of more profitable existing consumers.

The portfolio theory approach can be used to estimate the efficient risk-reward frontiers for the exporter's portfolios and to assess the balance between the two core priorities of demand security — increasing export volumes and increasing export prices. The next section will discuss this methodology in greater detail.

Policy tools

Energy exporters can utilize a variety of strategies to enhance their energy security. This section reviews the specific policy tools relevant to physical and price (revenues) security components with a focus on energy exports.

Domestic market policies greatly affect the export capacity and competitiveness of an energy exporter. A country's regulatory and policy environment can incentivize companies to engage in exploration and production activities that increase the supply of energy available for export. Authorities can achieve a similar impact by curbing domestic demand through energy efficiency standards and other demand management measures. Policymakers must also ensure sufficient investment in upstream and midstream infrastructure to maximize the potential of energy exports, including through public-private partnerships, and safeguard their physical security. Finally, maintaining a certain level of fuel stocks and managing spare production capacity can help alleviate fluctuations in demand and allow an exporter to quickly adjust to the current state of the market, although such measures carry additional costs.

Taxation provides another key policy lever for the entire energy export value chain, from exploration and production to transportation, refining, storage and exports. This includes tax regulations in downstream and adjacent industries, which have an indirect impact on energy exporters. An effective tax regime for the energy industry requires authorities to balance the competitiveness of domestic and international markets on the one hand, and fiscal revenues and risk of counter-actions from trading partners and foreign competitors on the other. Regardless of tax levels, the stability of the regulatory environment is essential for the long-term planning, investment, and overall development of the energy-exporting industry.

Domestic energy price incentives distort demand and reduce the availability of energy supplies for the export market. This not only decreases export revenue but also can depress investment in energy production and throughout the energy export value chain. Conversely, if domestic prices follow the global market, increased domestic demand generally benefits producers by offering additional revenue in the local market, presumably with lower risks than associated with exports.

In the foreign trade domain, diversification remains a central risk mitigation strategy for importers and exporters alike. Energy exporters can diversify their exports in several ways. The diversification of buyers (markets) can help reduce counterparty risks and avoid excessive dependence on a given market. This is often combined with the diversification of transit routes and modes in order to avoid or reduce exposure to individual logistical chokepoints and transit nodes. Finally, diversification across fuel types and products further increases the stability of export revenues by reducing the potential impact of systemic risks (that cannot be diversified across consumers) associated with a particular global commodity market.

However, diversification can become costly. The management of operations across additional markets and shipping routes requires extra resources and sometimes reduces the share of the most profitable or efficient ones. The optimal diversification level should be defined by the exporter's perception of risks associated with particular buyers, supply routes, and global energy markets; the portfolio approach presented in the next section provides a method for this assessment.

Financial derivatives serve as another important tool for risk management, particularly for hedging the downside price risk and volatility of traded energy commodities, as well as exchange rate fluctuations. Major energy derivatives include futures, options, and swaps, among other instruments. Standard contracts can be purchased on exchanges, and custom ones can be arranged with banks or bilaterally between parties.

Energy exporters typically determine their hedging strategies based on their export contract terms. They can choose from a range of options for both shipping and payment arrangements, depending on their strategies for specific markets, risk tolerance, and targeted energy export portfolio parameters. Supply arrangements vary from structured long-term contracts to spot sales and can specify total volume or detailed shipping schedules. Additional clauses that can benefit exporters include 'take-or-pay' and 'no re-sell' agreements. Pricing terms also vary significantly, from fixed prices for the duration of a contract to variable schemes that link the prices of individual shipments to commodity benchmarks, indices, or hub prices, with a variety of hybrid pricing systems in between. Exporters may also opt for 'cost, insurance and freight' (CIF) pricing, which captures logistics margins and the associated risks, in lieu of more conventional 'free-on-board' (FOB) arrangements, in which they deliver shipments at their own borders.

However, factors outside the control of energy exporters can limit their ability to effectively manage risks through the terms of their export contracts. These include global and regional energy market trends, the dynamics of bilateral relations, and the bargaining power of buyers and transit countries. These variables, in turn, largely depend on the specifications of exported fuels (e.g., the market conditions may significantly differ for light and heavy crudes), the geographic locations of export nodes, and availability of shipping modes and routes.

Vertical integration across global energy value chains can also enhance the energy security of exporters. Acquiring midstream and downstream energy assets (or stakes in them) in foreign markets can give an investor control over fuel supply management, increasing the security and predictability of foreign demand for energy produced in the domestic market. Greater control over such assets can also enable price management across the value chain, including transfer pricing. In addition, this strategy can alleviate existing or potential market access barriers in key target markets. The resulting physical presence in key energy trading hubs also increases the flexibility and scope of operations (spot trading, swaps, etc.), further diversifying the revenue streams.

The penetration of Saudi Aramco into its key target markets provides a good example of the vertical integration strategy. The company has established its presence — primarily through joint ventures — in the refining and logistics sectors of Europe, the U.S., Southeast Asia and across the major East Asian markets. However, its attempts to gain control over midstream and downstream energy assets can be perceived as an energy security (or even national security) threat by energy-importing countries. Asset swaps, in which the importers gain control over foreign energy upstream assets in return for a stake in their midstream and downstream operations, can mitigate such concerns. The EU denied the attempts of Russia's natural gas exporter Gazprom to bid for regional distribution companies in the EU; however, the company managed to conclude a deal swapping its natural gas and condensate production assets for the trading and storage business of BASF in Germany and Austria.

Portfolio Optimization of Energy Exports

Scope, method and data

This paper explores the growth-volatility and price-volatility dynamics of oil export portfolio structures for five GCC economies: Kuwait, Oman, Qatar, Saudi Arabia and the UAE. (We exclude Bahrain, whose current oil export structure does not permit construction of an efficient frontier portfolio). This approach provides an innovative assessment tool for the two major pillars of energy security — security of demand and price optimization — from the exporter's perspective. It can be applied to assess the current composition of the energy export portfolios, test the potential impacts of market development scenarios, and help inform relevant response (prevention) strategies.

A country's energy exports generally comprise a set of flows to different buyers that vary in volume, growth rate, and price terms. These can be represented as a portfolio, in which the total export volume growth rate (or export price) equals the weighted sum of the relevant values associated with specific buyers, and where these total portfolio characteristics are subject to a diversification effect. In this case, the return is represented by the export growth rate (or export price), and uncertainty as to the underlying volatility of the return variables. Under these assumptions, energy exporters will strive to maximize their expected portfolio returns for a given level of risk or, conversely, minimize the risks associated with a certain level of expected returns.

Markowitz (1952) first introduced the conceptual formulation of the portfolio model, and it has since been applied extensively in financial analysis as well as other fields. However, its utilization in the energy sector remains limited, especially in the areas of energy trade and energy security. For a detailed review of portfolio theory, including its applications and limitations, see Galkin, Bollino, and Bigerna (2019).

To assess the trade-offs facing oil exporters we construct two efficient portfolio frontiers for the five countries in focus with the following characteristics:

> The oil export volume growth portfolio: The return variable is represented by the monthly growth rate of oil export volumes and variance is derived from the structural composition of the portfolio, based on historical export data for individual buyers. This portfolio represents the trade-off between higher growth and concentration, and lower risk through diversification.

> The oil export price portfolio: The return variable reflects the average monthly price received by the exporter. Portfolio variance is estimated based on fluctuations in the price paid by individual buyers and their respective shares of the total oil exports of each exporter. This represents the trade-off between a portfolio concentrated on fewer buyers offering the best price terms, and a more diversified one with a lower expected return.

These portfolios cover the two primary aspects of energy security from the exporter's perspective: securing demand and obtaining favorable price terms while minimizing the associated risks (see Appendix for a detailed explanation of how we construct the efficient portfolio frontiers, including modeling specifications).

Next, we develop several scenarios to assess the potential impacts on the above portfolios from changes in portfolio composition, demand shocks, and shifts in global oil shipment patterns.

The dataset used in this study comprises monthly volumes and prices of crude oil exports for each of the GCC members, disaggregated by destination country. However, the GCC countries do not publicly release direct exports data, nor make it available to open source data platforms, such as those provided by the World Bank or International Trade Centre. Therefore, we used these sources to obtain the 'mirror' exports data, i.e., the monthly volumes and prices of crude oil imported from each of the GCC countries by every other economy in the world included in the platforms. To determine a proxy for the price at the exporter's border, we subtracted the estimated shipping costs (calculated on a per unit, monthly basis for all major oil export routes from the GCC ports) from the corresponding price recorded at the importer's border.

We note that the model's output reflects relatively short-term effects, as the portfolios are calibrated using monthly exports data. Risk assessment in this study is also limited to the specific risks associated with a particular buyer/export route that can be diversified. It does not include systemic risks (such as the COVID-19 pandemic) that can destabilize an entire industry, market, or the entire global economy.

Regarding the issue of seasonality, financial market analysis has demonstrated mixed evidence: equity market returns show significant seasonality in advanced economies but not in emerging markets (Li et al. 2018). Some seasonality exists in future markets for gas (Moreno, Novales, and Platania 2019) but not for oil; seasonality is arguably negligible according to Inchauspe, Li, and Park (2020).

The Appendix contains a detailed description of the model and data sources used in this study.

Scenario design

We develop several scenarios to test how the oil export portfolios of the five GCC countries perform under various demand and logistics shocks.

First, we establish a baseline scenario — Baseline 2018 — by identifying the positions on the countries' efficient frontier curves that correspond to their respective average monthly oil exports data for 2018. Then, we test the short-term impacts of a sharp increase in Chinese oil imports, and subsequently assess the longer-term consequences of potential redistribution of global oil import flows by reducing the shares of the U.S. in the export portfolios of the five countries and redistributing this among the other importers. Finally, we test the resilience of the portfolios to a logistics shock caused by a blockade of the Malacca Strait. Table 3 summarizes the scenario inputs.

Table 3. Energy security scenarios for oil export portfolios.

Scenario	Description
Baseline 2018	We estimate the point on each exporter's efficient frontier curve that most closely corresponds to the average monthly growth rates of oil export volumes and export prices in 2018.
Increased Chinese demand	We increase oil export volumes to China by 20% over Baseline 2018 levels for each exporter; flows to other markets remain unaffected.
Exports redistribution	We reduce the shares of U.S. imports by 20% compared with Baseline 2018 levels for each exporter; we then redistribute these volumes among the other buyers in proportion to their Baseline 2018 shares.
Malacca strait blockade	We assume that the Malacca Strait is blocked, increasing the transit time of oil cargoes to East Asia by 3.5 days; this leads to a 20% reduction in export volumes to that region, while other markets remain unaffected.

Results and Discussion

Efficient frontiers of oil exports

Empirical estimations allow us to construct the relevant arm of the efficient frontier (given by equation A1 in the Appendix), which represents a quadratic relation between the standard deviation of the growth rates (the risk measure) and average growth (the return measure). In other words, this makes risk an increasing function of return: the higher the growth rate of the target variable, the higher the associated dispersion of the portfolio composition, which means higher risk.

Figure 2(a) shows the efficient frontiers for growth of crude oil export volumes. This reflects the trade-off between the monthly exports growth rate (shown on the vertical axis) and associated risk, represented by the standard deviation of exports growth rate (the horizontal axis). The black dots on the chart represent the average monthly oil export growth recorded in 2018, which serves as the baseline for scenario analysis. For instance, the return-risk combination for Saudi Arabia gives an average growth rate for oil exports of 1.05 and a standard deviation of 0.047.

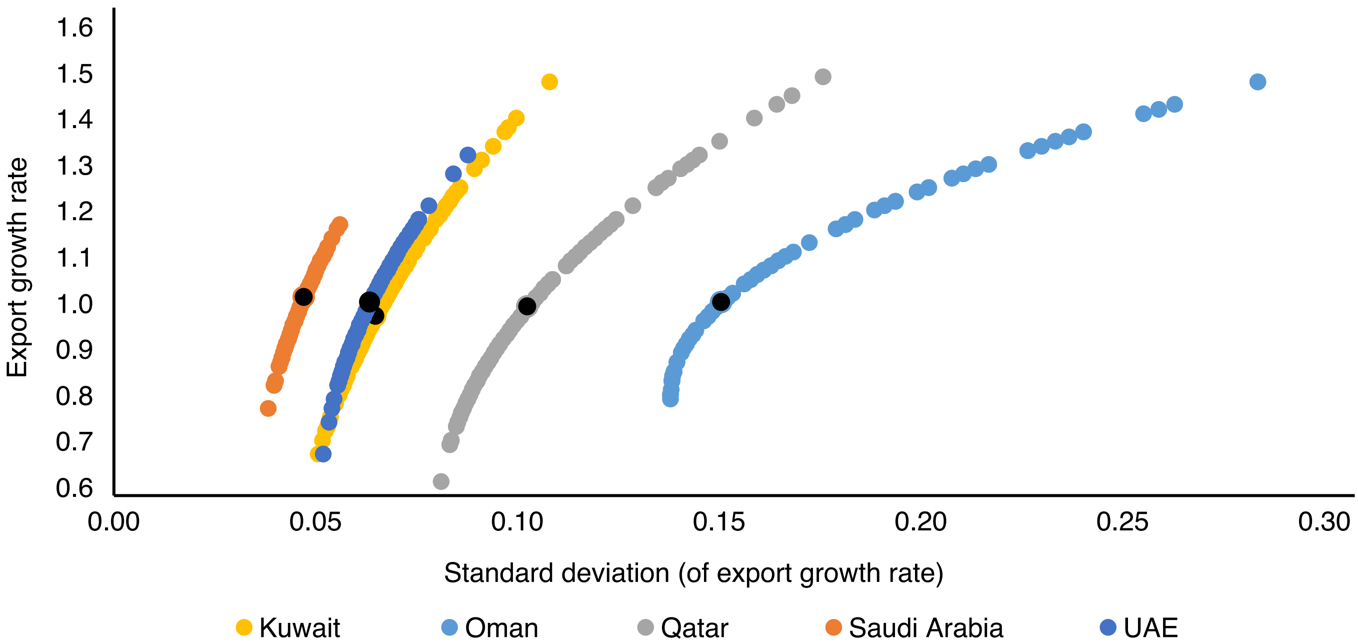
Considering the return-risk combination for the countries analyzed, note that the 2018 average monthly growth rates for the five countries fall within a narrow range: from 0.992 for Kuwait to 1.023 for Oman. However, the volatility of oil export growth in any given month varies substantially: the month-on-month changes in exported oil volumes can exceed 20%. This explains the shape of the efficient frontier curves, which — with the exception of Saudi Arabia's — apply even in cases of +/-30% monthly growth fluctuations.

We observe a broader range of standard deviations for 2018 export growth. Saudi Arabia (0.047) exhibits the least volatility, followed by Kuwait (0.062) and the UEA (0.064), while Qatar (0.1) and Oman (0.15) show much higher levels. Thus despite their similar export growth rates, the countries demonstrate wide variance in risk levels, which can be explained by differences in the composition of their export portfolios. Based on the risk profiles represented by the efficient frontier curves, we can identify three groups of oil exporters with similar characteristics.

Saudi Arabia holds the lowest risk oil export portfolio of the five countries. The Kingdom's steep efficient frontier curve suggests that it can increase oil exports without significantly raising its portfolio risk level, a strong position that results from the country's production profile and market strategies. Saudi Arabia is by far the largest oil exporter in the GCC, exceeding the second biggest — the UAE — by almost threefold. Its export growth over the total observation period has also been relatively smooth, on average 0.3% per month. Despite the Kingdom's significant spare capacity margins and historical role as the 'swing producer' to balance global markets, monthly fluctuations in its oil export volumes rarely reach 10%. Saudi Arabia also has the most diversified oil export portfolio in the GCC, with a 2018 HHI score of 1,015 — well below the 1,500 competitive market threshold. Furthermore, Saudi Arabia has established a strong downstream presence — primarily through joint ventures — in key target markets across the globe.

Kuwait and the UAE have similar efficient oil export frontiers. The two countries demonstrate similar historical patterns of oil export growth: a sharp increase until 2012-2013, followed by a plateau with average monthly export volumes of 10.2 million tonnes for the UAE and 8.2 tonnes for Kuwait. They each export more than twice as much oil as Qatar or Oman, though far less than Saudi Arabia. Both Kuwait and the UAE have relatively diversified export portfolios, with 2018 HHI values of 1,357 and 1,584, respectively. In the case of Kuwait, its lower HHI compensates for the volatility associated with higher average monthly exports growth (1.9% over the observed period) and monthly exports fluctuations that often reach double digits. The UAE has a more concentrated export portfolio due to the large share taken up by Japan, which accounts for over 30% of its oil exports. However, the UAE has recorded more modest export growth than Kuwait, 0.8% monthly on average, with a lower magnitude of monthly fluctuations.

Figure 2(a). Efficient oil export frontiers: export growth rate.



Source: KAPSARC research.

Note: Black dots represent average monthly values observed in 2018.

The Kuwait-UAE comparison demonstrates that diversification can alleviate the risks associated with aggressive exports growth and fluctuations, while more consistent oil export flows need not be excessively diversified to avoid associated costs. However, we note that the two countries fall at the opposite poles of economic dependency on oil exports within the GCC. Petroleum exports amounted to over 90% of Kuwait's total exports and 47% of its GDP in 2018, versus 29% and 22% for the UAE, respectively (see Table 2).

The oil export portfolios of Qatar and Oman exhibit significantly higher risk levels than those of their GCC peers, with standard deviation for their 2018 exports of 0.1 and 0.15, respectively. The shapes of their efficient frontiers also suggest a sharper increase in volatility associated with potential monthly export growth. This may be less concerning for Qatar, as its oil exports have been declining in recent years, and the country derives most of its energy export revenue from natural gas. Despite the relatively higher risk profile of its oil export portfolio, Qatar has increased its diversification in recent years, reducing HHI from high concentration levels in 2013-14 to 2,262, indicating moderate concentration, in 2018.

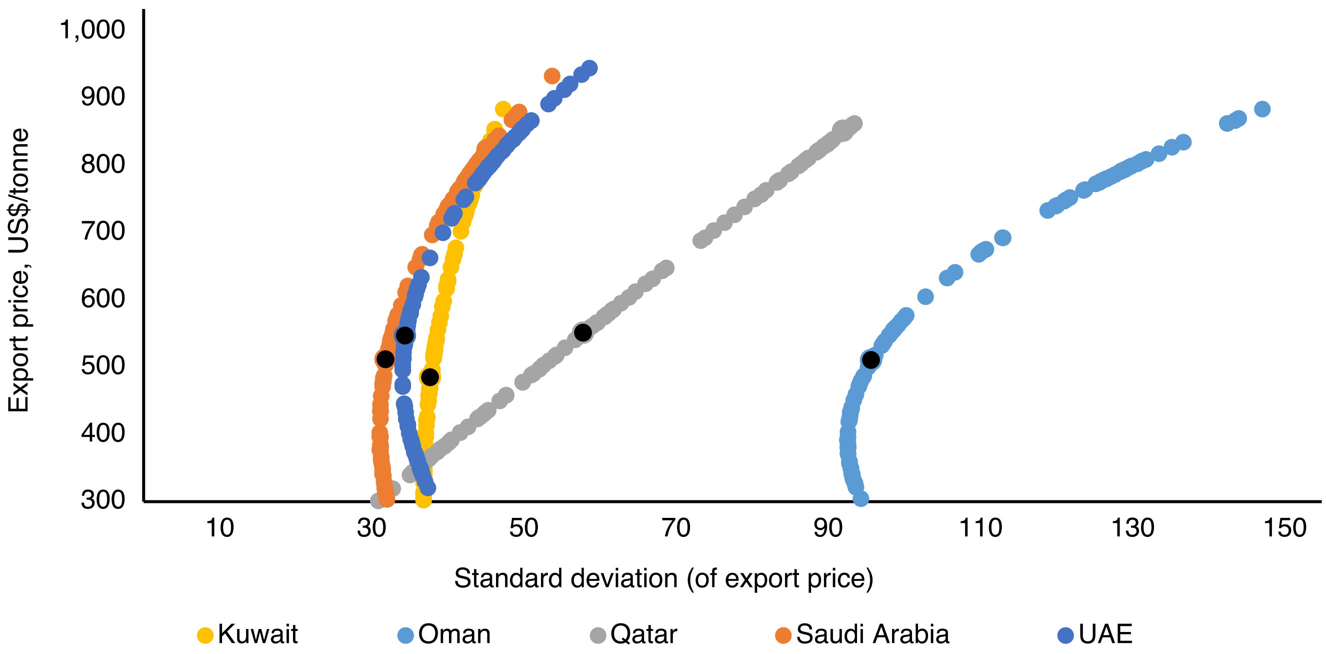
Oman, on the other hand, has been steadily increasing its oil exports, which climbed over 40% between 2008 and 2018. Most of this export growth has been absorbed by China, whose share of Oman's total oil exports reached a staggering 76.6% in 2018, raising the country's oil export HHI to 6,098. Such heavy reliance on a single buyer, along with relatively small total export volumes and intensive growth dynamics, make Oman's oil export portfolio the riskiest in the GCC.

We have also used the quadratic relationship between risk and return (equation A1 in the Appendix) to estimate the link between the oil export price (the measure of return) and the standard deviation of the prices to the portfolio of customers (the risk measure). We infer that the higher the price, the higher the associated dispersion of the portfolio composition, reflecting higher risk.

Figure 2(b) shows the oil export price versus risk relationships for the five GCC exporters covered in this study. The vertical axis represents oil export prices in US$ per tonne, calculated on a monthly weighted average basis. The horizontal axis shows the standard deviation of prices, representing the associated risk. For instance, the return-risk combination for Saudi Arabia is 514 U.S. dollars (US$) per tonne and 31.9 export price standard deviation.

The estimated price levels for the 2018 Baseline scenario differ considerably among the countries in focus. Kuwait recorded the lowest level (US$497.2/tonne), followed by Oman (US$514.8/tonne), Saudi Arabia (US$517.5/tonne), the UAE (US$539.1/tonne) and Qatar (US$553.4/tonne). We note that meaningful comparison of average oil price levels for the GCC exporters is rather problematic due to underlying differences in the characteristics of their exported crudes and large fluctuations in global oil prices over the course of the year. In this regard, analysis of the slope and position of their oil portfolio frontier curves appears to be more informative.

Figure 2(b). Efficient oil export frontiers: export price.



Source: KAPSARC research.

Note: Black dots represent average monthly values observed in 2018.

The oil export portfolios of the UAE, Kuwait and Saudi Arabia are the most efficient in terms of export price relative to risk. Their standard deviations of the average 2018 oil export prices fall within the range of 31.9-37.8; for export prices above US$750/tonne, the risk profiles of these countries converge at a standard deviation of around 42. Saudi Arabia's portfolio has the lowest risk profile for the average monthly price levels observed in 2018, followed by the UAE's. While Kuwait's is slightly riskier, the steep slope of its efficient frontier curve suggests that its portfolio is well-positioned for a steep price increase.

As illustrated by the shape of its frontier curve, Qatar exhibits an almost linear relationship between export price and associated volatility. The country recorded average price volatility in 2018 of 57.9, second highest among the five GCC states. As with export price growth above, Oman has the riskiest oil export portfolio of the five countries in terms of price volatility. Moreover, the shape of its frontier curve suggests an exponential increase in volatility in the event of substantial price growth.

We note that in terms of their efficiency frontiers, the export price portfolios seem to be less affected than the export growth portfolios by diversification. Saudi Arabia, the most diversified exporter of the group, demonstrates only a slightly more efficient export price frontier than significantly less diversified UAE or Kuwait.

Comparison of the efficient frontier curves shown in figures 2(a) and 2(b) shows the trade-offs between the physical supply and price components of energy security from the exporters' view. This approach can also provide insights into the exporter's priorities along these energy security dimensions. For instance, these figures indicate that Saudi Arabia focuses more on pursuing diversification and capturing major demand markets, reflected by its efficient export growth portfolio, than on simply maximizing price benefits. The Kingdom also has the least vulnerable export portfolio to a potential price war among the group because it can ramp up exports without a significant increase in associated risks, while the reduction of export prices from the levels observed in this study would only have a minor impact on its portfolio volatility. At the other end of the spectrum, the export portfolios of Qatar and Oman would be highly vulnerable to such scenarios.

In general, oil exporters covered in this study seem to demonstrate a balanced approach to minimizing risks associated with both export growth and pricing — unlike some major oil importers that tend to prioritize either the physical supply or price component of energy security (see Galkin, Bollino, and Bigerna 2019). However, the GCC countries vary considerably in terms of the efficiency of their oil export portfolios. In particular, the portfolios of Qatar and, especially, Oman could be further optimized to achieve more sustainable export growth with lower price risk.

Scenario analysis

In order to test the resilience of the five countries' oil export portfolios derived in the previous section, we estimate the impacts of potential demand shocks and logistical disruptions according to the scenarios stated in Table 3. We use monthly average export volumes, weighted average monthly export prices, and associated volatility levels observed in 2018 as a baseline for comparison.

The simulations are implemented by shocking the target variable and computing the hypothetical new return-risk efficient combination (ceteris paribus). In other words, the simulations represent new portfolio reallocations based on the assumption that a demand shock implies a new overall growth rate (the return measure) and a new standard deviation due to the shifting shares of individual importer countries (the risk measure). In the following analysis, we report the differences between the baseline and the scenario; thus, a change in return (risk) of x% means that the overall export volume (standard deviation) increases by x% relative to the baseline.

Note that demand disruptions under these scenarios do not impact the export growth rates but rather represent a one-time shift in demand from a particular buyer or a group of buyers, resulting in a deviation from the benchmark efficient frontier. For the increased Chinese demand and the Malacca Strait blockade simulations, we do not test the effects of disruptions on price portfolios, as such events would have a significant systemic impact on oil prices globally (as mentioned earlier, the impact of systemic risks on the exporters' portfolios lies outside the scope of this study).

In the first simulation, we increase the monthly export volumes of the five countries to China by 20% over the Baseline 2018 scenario, without altering their exports to other destinations. These extra volumes would constitute a 5.5% increase in China's total oil imports. A shift of this scale could hypothetically occur due to a surge in China's demand, or to disruptions in its other energy import supply chains, such as pipelines to neighboring countries. We also assume that all GCC exporters are capable of providing these extra supplies — an estimated 3.9% increase in their combined average monthly exports — given that their maximum monthly export volumes significantly exceed the average 2018 levels. In addition, the GCC exporters tend to maintain spare production capacity and crude oil stocks.

We assess the impact of this scenario on the five countries' oil export portfolio performance — specifically, the shift in export volumes and resulting portfolio risk expressed by the standard deviation. Table 4 presents the results.

Table 4. Effects of increased oil exports to China.

Exporter	Changes compared with Baseline 2018	
	Export volumes	Standard deviation
Kuwait	4.7%	2.2%
Oman	15.3%	11.7%
Qatar	0.7%	0%
Saudi Arabia	3.3%	-8.8%
UAE	2.0%	-1.0%

Source: KAPSARC research.

The impact of this surge in demand from China on the oil export portfolios of the five countries depends on the size of China's current share of their export sales. Oman's export volumes would spike 15.3% since China already accounts for over three-quarters of its oil exports. Kuwait and Saudi Arabia, whose oil exports to China in 2018 amounted to 23.7% and 16% of their totals, would record more moderate rises of 4.7% and 3.3%, respectively. The UAE and Qatar would see the least impact due to China's small shares of their exports.

However, under this scenario, portfolio risk primarily shifts according to each country's portfolio composition and the specifics of its existing bilateral export contracts with China, such as the committed volumes and regularity of shipments. Generally, an increase in export growth leads to higher risk (volatility). Oman again exhibits the largest increase (11.7%); we note that in addition to the extreme concentration of China in its oil export portfolio, Oman already has the highest baseline risk profile (see Figure 2a). Kuwait would see a less pronounced rise in export portfolio volatility (2.2%), while Qatar records zero impact. Conversely, the portfolio risk levels for the UAE (-1.0%) and Saudi Arabia (-8.8%) decline with increased exports to China. This indicates that China is one of the most reliable buyers for these countries and is currently underrepresented in their portfolios.

In the second scenario, we reduce the share of the U.S. in the five countries' portfolios by 20% and proportionally redistribute these volumes among their other buyers. This allows us to assess the effects of portfolio restructuring without a change in volume.

For the period of 2019-2021, the U.S. Energy Information Administration projects as its base case scenario that the U.S. will decrease crude oil imports at an average rate of 7.4% annually (EIA 2019). We assume that the oil imports from the GCC could drop at a faster pace due to potential substitution from less remote regions, such as the Americas or Europe. In this simulation, we also estimate the impact on export price portfolios, assuming that the decline in the U.S. imports is compensated by increased demand from other regions and, therefore, would not have a significant impact on the systemic oil price risk.

The redistribution of oil export flows according to this scenario would impact only two GCC exporters, Kuwait and Saudi Arabia (see Table 5). The others either exported minimal or no oil to the U.S. in 2018.

Since the affected volumes are proportionally distributed to other buyers, there is no impact on total export volumes or portfolio growth rates. However, the export portfolio risk levels (standard deviations) under this scenario do vary from the baseline. While Kuwait sees a 1% increase, Saudi Arabia actually reduces its portfolio volatility by 13%.

The redistribution of the U.S.-bound export volumes also improves the performance of export price portfolios of the affected exporters. The changes in average export prices compared with the 2018 Baseline scenario are positive, though tiny (as expected, given the global nature of the crude oil market). Monthly weighted average export prices would increase by 0.05% (or US$0.25/tonne) for Saudi Arabia and 0.04% ($0.19/tonne) for Kuwait. However, while this scenario does not measurably impact price volatility for Saudi Arabia, for Kuwait it brings a 12.1% reduction. This can be explained by the intermittent nature of shipments to the U.S., which raises short-term volatility despite the fact that the country accounts for only 4% of Kuwait's oil export portfolio.

Table 5. Effects of decreased oil exports to the U.S.

Exporter	Changes compared with Baseline 2018		
	Standard deviation (of export growth)	Weighted average price	Standard deviation (of export price)
Kuwait	1.0%	0.04%	-12.1%
Oman	-	-	-
Qatar	-	-	-
Saudi Arabia	-13.0%	0.05%	0%
UAE	-	-	-

Source: KAPSARC research.

The observations derived from this scenario indicate that the expected decline in U.S. oil imports, even at a faster than expected pace, will not negatively affect the GCC exporters if offset by increased demand from importers in other regions. Notably, both Saudi Arabia and Kuwait have already been decreasing oil exports to the U.S. as a share of their portfolios, from 21.3% and 12.2% in 2008 to 12.3% and 4.0% in 2018, respectively.

Finally, we simulate the impact on the five oil export growth portfolios of an external shock unrelated to supply/demand fluctuations in the oil market. As an example of a global supply chain disruption, we model the consequences of a blockade of the Malacca Strait, which would add an estimated 3.5 days (or approximately 20%) to the shipping time from the GCC to major consumers in East Asia (China, Japan, South Korea, Taiwan and the Philippines). Therefore, we assume that, in the short term, monthly exports reaching these destinations would drop by 20% without substitution from other importers.

In contrast with the previous scenario, the impact of the Malacca Strait blockade would be significant for all GCC exporters (see Table 6). Oman would suffer the largest drop in export volumes (-16.6%), again due to the dominant share of China in its oil exports portfolio, followed by Kuwait (-13.6%). The UAE, Qatar, and Saudi Arabia would also see sizeable reductions.

We expect that such a significant reduction in export volumes would lead to a partial 'de-risking' (i.e., reduction in the standard deviation) of the exporters' portfolios. Saudi Arabia demonstrates the largest such adjustment (-16.1%), followed by the UAE (-8.2%). However, Oman and Qatar record only small declines in portfolio risk levels, and Kuwait sees the standard deviation of its oil export volumes increase by 2.7%. This indicates that the current composition of Kuwait's portfolio is the most vulnerable to potential disruption among the five countries.

Table 6. Impacts of the Malacca Strait blockade.

Exporter	Changes compared with Baseline 2018	
	Export volumes	Standard deviation
Kuwait	-13.6%	2.7%
Oman	-16.6%	-1.4%
Qatar	-10.0%	-2.8%
Saudi Arabia	-9.8%	-16.1%
UAE	-10.0%	-8.2%

Source: KAPSARC research.

The observed results of the Malacca Strait blockade scenario show that the demand security of oil exporters can be affected not only by shifts in demand and importer behavior, but also by the physical security and reliability of export routes and supply chains. The portfolio approach can help exporters diversify and approach their risk analysis accordingly.

A sufficient level of diversification and a balanced export portfolio can also alleviate the impacts of systemic risks. For example, the ongoing COVID-19 pandemic has induced a sharp drop in overall global oil demand. However, the magnitude and dynamics of changes in oil imports have varied widely among major importing economies: in March 2020, crude oil imports increased by 4.5% in China, fell by 4.9% in the U.S. and plummeted by 50.6% in France (ITC 2020). Thus, overreliance on a given import market can magnify the vulnerability of an exporter to turbulence in world oil markets and the broader global economy.

Conclusion

The exporter's perspective has traditionally been underemphasized, and even ignored, in the energy security domain. As a result, energy security policy and research have often failed to address the reciprocal nature of importer-exporter security in general and demand security in particular.

Energy-exporting countries and the international organizations that represent their interests can help correct this imbalance by developing and articulating comprehensive energy security policies and strategies. At the global level, this would convey the perspective of energy exporters and foster beneficial producer-consumer dialogue. Significant untapped potential exists for cooperation across a number of energy security spheres in which the interests of energy exporters and importers converge, including enhancing the security of physical supplies and supply chains, promoting transparent market mechanisms, facilitating energy investment, and reducing price volatility to increase the stability of global energy markets.

For energy-exporting countries, developing more comprehensive energy security policies that encompass export and demand and security would help identify relevant challenges and threats, as well as applicable policy tools and mitigation strategies. Given the economic importance of energy exports, this should constitute an essential part of their broader energy, national security and economic development agendas.

As this study has shown, portfolio theory presents a useful tool for optimizing energy exports according to an individual exporter's priorities. It captures both the export growth and price maximization components of energy demand security in foreign trade, as well as the associated risks and trade-offs. Oil exporters covered in this study demonstrate a balanced approach to minimizing risks associated with both export growth and pricing — unlike some major oil importers that tend to prioritize either the physical supply or price component of energy security. However, the analysis of the oil export portfolios of the five GCC countries highlights that resilience to demand and supply chain shocks varies significantly despite similar patterns in product specifications and diversification levels observed for some of the countries.

This approach could also be utilized to assess portfolios comprising different combinations of export fuels and supply chains. More broadly, further research in the domains of export and demand security for fuel exporters could increase the understanding of systemic energy sector risks and facilitate the development of new indicators, frameworks and tools for energy security policy.

Endnotes

1 “Uninterrupted availability of energy sources at an affordable price” (IEA 2018).

2 “The continuous availability of energy, in varied forms, in sufficient quantities, and at reasonable prices” (UNDP 2000).

3 “The European Union’s long-term strategy for energy supply security must be geared to ensure … the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concerns and looking towards sustainable development.” (European Commission 2000).

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Appendix: Estimation method, data, model output and diagnostics

Based on the standard portfolio theory, we assume that agents minimize portfolio variance for a given level of expected return (Galkin et al. 2019). In the first case, we consider as return the monthly growth rate in oil export volumes. The variance of the portfolio is the sample variance of the weighted growth rates of exports to individual buyers. In the second case, the return variable reflects the average monthly oil price recorded by an exporter. Thus, the portfolio variance is the variance of the weighted prices paid by individual buyers.

We derive the oil export portfolios according to these specifications for the five major oil exporters from the GCC region: Kuwait, Oman, Qatar, Saudi Arabia and the UAE. The data availability for Bahrain oil exports shows an erratic pattern to a narrow range of buyers. Thus, there is an insufficient history of oil exports data that does not allow to apply the portfolio analysis approach. Therefore, we leave Bahrain out of the scope of this study.

The exporters in focus do not report their oil exports data in open sources with the level of disaggregation required for this study. Therefore, we construct our dataset based on the mirror data, i.e., the oil imports from these countries reported by the buyers. The resulting dataset contains the monthly physical flows in tonnes between each of the GCC exporters in focus and their individual buyers (on the country level) and the values of these flows recorded in United States dollars (US$) on CIF basis.

To obtain a proxy for the FOB export price, we subtracted the shipping cost, estimated based on the historical monthly average shipping rates (expressed as US$ per nautical mile per tonne of crude oil) and the distances between the major export and import ports, from the CIF price.

Data are aggregated for each exporting country studied for the period T = (2008:1-2018:12) for a total of 132 monthly observations and a specific number of buyers. We preliminary noted that for each GGC exporter, the data sets contained a number of buyers that report very small amounts with an intermittent frequency. These are occasional flows for only one or a few periods, accounting for less than 1% of the total export flows. We decided to exclude these small occasional buyers, and therefore we consider the set of buyers that constitute 99% of the total exports. The number of buyers M considered for each country is: $M_{99,\ Kuwait} = 11$, $M_{99,Oman} = 4$, $M_{99,Qatar} = 4$, $M_{99,Saudi\ Arabia} = 24$, $M_{99,\ UAE} = 13$.

For the variable of flows in physical terms, we compute monthly growth rates and associated standard deviations for each buyer.

For the variable of flows in dollar terms, we compute a proxy of FOB price associated with each buyer in US$1,000 per tonne.

Formally, we label gt the return and SDt the standard deviation and et the error term in period t and we estimate the equation:

$$SDt = a + b_1\, g_t + b_2\, g_t^2 + e_t \qquad \text{(A1)}$$

To estimate equation (A1) we check for the cointegrating properties of the series applying the Dickey-Fuller test, finding that all series, as expected, have a unit root. We also perform the Engle-Granger tests (results are reported in Table A1). These tests are all showing that there exists cointegration, allowing to estimate the equation avoiding spurious correlation.

Appendix: Estimation method, data, model output and diagnostics

The results of the estimation of equation (A1) for the two variables for the five countries are reported in Table A2, with significance, sign and magnitude of the estimated coefficient values b1 and b2. All estimates confirm the theory (b1 negative and b2 positive). The significance is generally satisfactory. The sample period is 132 observations for all the quantity equations, while it is slightly lower for the price equations, as some outliers due to poor data quality have been eliminated from the estimation sample (as reported in Table A2). Note that the coefficient b2 greater than one indicates increasing diversification and vice versa. The empirical results show that diversification is decreasing for all countries.

Table A1. Cointegration analysis.

Kuwait

Oil export growth rate			**Oil export price**		
Engle-Granger test			Engle-Granger test		
TestStat	P-value	Number of lags	TestStat	P-value	Number of lags
-4.08	0.05	3	-3.94	0.076	2

Oman

Oil export growth rate			**Oil export price**		
Engle-Granger			Engle-Granger		
TestStat	P-value	Number of lags	TestStat	P-value	Number of lags
-7.26	0.0000	2	-5.24	0.005	2

Qatar

Oil export growth rate			**Oil export price**		
Engle-Granger			Engle-Granger		
TestStat	P-value	Number of lags	TestStat	P-value	Number of lags
-4.04	0.06	5	-6.24	0.000021	2

Saudi Arabia

Oil export growth rate			**Oil export price**		
Engle-Granger test			Engle-Granger test		
TestStat	P-value	Number of lags	TestStat	P-value	Number of lags
-5.42863	0.0005	7	-5.14	0.0017	10

UAE

Oil export growth rate			**Oil export price**		
Engle-Granger			Engle-Granger		
TestStat	P-value	Number of lags	TestStat	P-value	Number of lags
-3.53	0.18	5	-6.24	0.00012	2

Source: KAPSARC research.

Table A2. Estimation results.

Saudi Arabia

Oil export growth rate

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
132	7.99536 [.005]	.743078	-623.277	628.160	B1	-.046477	.237023E-02	-19.6085	[.000]
					B2	.045732	.181230E-03	252.341	[.000]

Oil price

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
121	2.18459 [.139]	.267000	490.278	-478.289	C	50.7070	16.1428	3.14115	[.002]
					B1	-.081492	.059105	-1.37877	[.168]
					B2	.906892E-04	.497976E-04	1.82116	[.069]

Kuwait

Oil export growth rate

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
132	2.87782 [.090]	.921818	-501.496	508.820	C	.020726	.369696E-02	5.60629	[.000]
					B1	-.027518	.899276E-02	-3.06005	[.003]
					B2	.044921	.355592E-02	12.6329	[.000]

Oil price

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
125	.618633 [.432]	.345385E-02	545.073	-537.831	C	39.9512	20.4962	1.94921	[.054]
					B1	-.032319	.077673	-.016088	[.078]
					B2	.319443E-04	.177831E-04	.471272	[.038]

UAE

Oil export growth rate

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
132	.343491 [.558]	.585577	-499.067	503.950	B1	-.071542	.424174E-02	-16.8663	[.000]
					B2	.062428	.461761E-03	135.195	[.000]

Oil price

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
124	9.03470 [.003]	.087965	563.667	-556.436	C	62.2361	24.7173	2.51792	[.013]
					B1	-.115303	.086953	-1.32604	[.187]
					B2	.117937E-03	.702448E-04	1.67894	[.096]

Oman

Oil export growth rate

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
132	2.33250 [.127]	.337132	-144.706	152.030	C	-.164623	.079148	-2.07994	[.040]
					B1	-.512102	.168608	-3.03724	[.003]
					B2	.312916	.074629	4.19297	[.000]

Oil price

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
113	6.72290 [.010]	.210473	557.258	-550.167	C	126.926	33.6888	3.76761	[.000]
					B1	-.175802	.127659	-1.37712	[.171]
					B2	.224627E-03	.110857E-03	2.02627	[.045]

Qatar

Oil export growth rate

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
132	.274269 [.600]	.756452	-413.722	418.605	B1	-.110250	.557593E-02	-19.7724	[.000]
					B2	.101710	.867553E-03	117.238	[.000]

Oil price

Number of observations	LM het. test	R-squared	Schwarz B.I.C	Log likelihood	Variable	Coefficient	Std. Error	t-statistic	P-value
119	15.9140 [.000]	.929742	383.951	-379.171	B1	.099246	.384566E-02	25.8072	[.000]
					B2	.104951E-04	.536812E-05	1.95508	[.053]

Source: KAPSARC research.

Notes: LM het.test: Lagrange multiplier heteroskedasticity test

Schwarz B.I.C.: Schwarz's Bayesian information criteria

Notes

About the Authors

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Philipp is a visiting researcher at KAPSARC, working on the economic and policy aspects of energy supply and trade. Philipp's work at KAPSARC includes evaluating the effect of preferential trade agreements on energy flows, analysis of OPEC energy policy and deriving insights related to China's energy policy and its impact on global markets through modeling energy supply sectors.

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Carlo Andrea is a visiting researcher at KAPSARC, a professor of economics at the University of Perugia, and a professor of energy economics at the University Luiss, Rome. He has been the president of the Italian Association for Energy Economics since 2014 and was the president of the International Association for Energy Economics in 2008. His other roles have included energy advisor to Italy's minister of industry, president of the Italian Electric Transmission Network, chief economist at Eni, economist at the Bank of Italy, research associate at United Nations' Project LINK, and lecturer and professor of economics at the universities of Pennsylvania (United States), Campobasso, Sassari and Urbino (Italy).

Carlo Andrea's research investigates econometric modeling, consumer behavior, energy markets, sustainable and renewable energy, liberalization and regulation policy. He has authored over 200 scientific articles, is the chief editor of the *Review of Economics and Institutions* and a member of the editorial board of *Energies*.

About the Project

This project assesses how the concept of energy security and the energy security strategies of suppliers and consumers have evolved following recent shifts in global energy markets, such as the increasing fungibility of energy, higher degree of interconnectivity of regional fuel markets, and rapid deployment of renewables. It studies the implications and potential directions of these developments, focusing on the economies of the Gulf Cooperation Council (GCC) and Northeast Asia. The project investigates opportunities for economic collaboration between the two regions, with an emphasis on Saudi Arabia and China. It sets out to identify the key drivers of the new energy security paradigm from the perspectives of both suppliers and consumers.

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