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"ASSESSING IMPACTS OF GLOBAL ECONOMIC DYNAMICS ON THE SAUDI ECONOMY AND OIL PRODUCTION: A GVAR ANALYSIS"

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Assessing Impacts of Global Economic Dynamics on the Saudi Economy and Oil Production: A GVAR Analysis

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Over the past decade, the global economy has witnessed fundamental changes, as well as geopolitical and macroeconomic crises, which have affected not just the economies of individual countries, but also the global economic links between the regions, countries, and various segments of the global supply chains. The magnitude of such impacts differs by individual economic sectors and countries. In this regard, Saudi Arabia and the Kingdom's relationship to the global oil market present an interesting case study. On one hand, Saudi Arabia's diversification efforts have led to increased integration into the global economic system and the rapid development of its domestic markets. The magnitude of oil price swings observed over the recent decade illustrates the increasing vulnerability of the Kingdom's oil sector to macroeconomic and geopolitical shocks. On the other hand, OPEC, and later the OPEC+ countries, have demonstrated increased coordination in their attempts to successfully stabilize the world oil market. This paper assesses the current relation of Saudi Arabia's economy, more specifically, its level of GDP and oil production, to various changes in the global economy.

To analyze these issues, we use KAPSARC's Global Vector Autoregression (GVAR) model, which is designed to analyze the potential implications of shocks to global markets. Specifically, we use the impact elasticities and correlation coefficients derived from a simulation of the GVAR conducted in November 2023 and compare these outputs to the one derived under the 2013 conditions—a year characterized by tight oil market conditions. We find that the impact elasticity of an increase in foreign GDP on its domestic counterpart is lower for Saudi Arabia than for their regional peers (except for Iran), as well as for most developed nations. In the oil production sector, the cross-country correlations are relatively weak and would appear to be weaker in loose market conditions with the correlation levels falling gradually over the past decade.[1] This is particularly true for Saudi Arabia, where less than 10% of the changes in its production is contingent on and can be explained by changes in oil production from the rest of the world.

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Introduction

Over the past decade, the global economy has witnessed fundamental changes. The COVID-19 pandemic and consequent macroeconomic stresses, technological advances in energy, automation/robotics, artificial intelligence, digitalization, and other factors have forced governments to implement fundamental changes in economic policy and regulation. Geopolitical crises have further complicated this backdrop, where supply-chain crises and the resulting friendshoring have started redefining how various economies relate to each other.[2] All these developments possibly induce what some are calling the emergence of a potential "new global economic order" (Buti and Fabbrini, 2023; Gouvea and Gutierrez, 2023).

Saudi Arabia occupies a unique position in this evolving setup. The Kingdom has started undertaking substantial reform. The private sector has started adopting innovation with an export orientation, while new trade partners, mostly from non-OECD countries, have solidified their partnership with the Kingdom through various institutional means. As a result, Saudi Arabia is diversifying its economy, developing a competitive labor market, and engaging in global investments with implied reinvestment and repatriation of profits. In addition, the economic diversification efforts undertaken by the Kingdom facilitate the development of the domestic market. This trend has resulted in Saudi GDP growth outpacing its exports and imports: In 2013, imports of goods and services in the Kingdom amounted to 30.5% of its GDP, substantially above the 2022 ratio of 23.3%. Similarly, its exports as a percentage of GDP decreased from 51.4% to 40.2% over the same period (World Bank, 2023).

The global resilience of fossil fuels in the aftermath of the pandemic singles out Saudi Arabia as an interesting case study. Saudi Arabia has maintained its dominance in the global oil industry while simultaneously increasing investments in low-carbon energy technologies (Bradshaw *et al.*, 2019). Development of solar and wind sectors at home and abroad,[3] further investments in carbon management systems, and an increasing focus on hydrogen all carry the potential to integrate Saudi Arabia into the global economy in ways that extend beyond its conventional role (Atalay *et al*., 2016).

All these developments suggest that this is a good time to (re)assess how the Saudi economy stands *vis-a-vis* major economies in the world. Accordingly, this paper assesses the current relation of Saudi Arabia's economy, more specifically, its level of GDP and oil production, to various changes in the global economy. To analyze these issues, we use KAPSARC's Global Vector Autoregression (GVAR) model, designed to analyze the potential implications of shocks to global markets (Considine *et al*., 2022). Specifically, we use the impact elasticities and correlation coefficients derived from a simulation of the GVAR conducted in November 2023 (Considine *et al*., 2023b). The GVAR Model is part of KAPSARC's Oil Market Rebalancing Project; see Appendix A.

How Important are Foreign Linkages to Domestic GDP and Oil Production in Saudi Arabia?--The Impact Elasticities of Their Domestic Counterparts

The GVAR modeling approach is a simple and effective means by which the complex and dynamic interactions in the global economy can be represented and analyzed. It can be summarized effectively by a two-step process. In Step 1, we estimate smaller country-specific models conditional on the rest of the world. These individual country-specific models are known as augmented VAR models or VARX* models, comprised of domestic country-specific variables and weighted cross-section averages of foreign variables, commonly referred to as "*" or "star variables." In Step 2, we estimate the individual models in stacked form, as a group, and solve them simultaneously as one large model utilizing a trade matrix and taking account of the flows of goods and services to and from each individual country represented in the GVAR (Chudik and Pesaran, 2016).

The importance of foreign linkages can be derived from the individual estimations of country-specific VARX* models of the GVAR. The estimated coefficients of the contemporaneous foreign variables on their domestic counterparts are known as the "impact elasticities" and are shown in Table 1 on the next page.[4] The elasticities reflect the international linkages between domestic and foreign variables and show how an individual country is affected by changes in foreign variables such as GDP and crude oil production.

The estimated coefficients measure the contemporaneous variable of a domestic variable in response to a 1% change in the corresponding foreign counterparts and provide valuable information about the relationships between domestic and foreign variables. In the case of Saudi Arabia, a 1% increase in foreign real GDP that is specific to Saudi Arabia[5] in any given quarter is associated with an increase of 0.31% in real GDP in Saudi Arabia in that same quarter. As shown in Table 1, the results are statistically significant at the 5% level.

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Table 1
The Contemporaneous Effects of Foreign Variables on Their Domestic Counterparts: GDP

		Y_{it}			Y_{it}
Argentina	Coefficient	0.853 *	**Norway**	Coefficient	0.313 ***
	White's adjusted SE	0.367		White's adjusted SE	0.130
	Newey-West's adjusted SE	0.439		Newey-West's adjusted SE	0.103
Australia	Coefficient	0.380 ***	**Peru**	Coefficient	1.121
	White's adjusted SE	0.092		White's adjusted SE	1.254
	Newey-West's adjusted SE	0.084		Newey-West's adjusted SE	1.199
Brazil	Coefficient	0.212 *	**Philippines**	Coefficient	0.340
	White's adjusted SE	0.153		White's adjusted SE	0.234
	Newey-West's adjusted SE	0.118		Newey-West's adjusted SE	0.269
Canada	Coefficient	0.768 ***	**Russia**	Coefficient	0.583 ***
	White's adjusted SE	0.138		White's adjusted SE	0.227
	Newey-West's adjusted SE	0.185		Newey-West's adjusted SE	0.175
Chile	Coefficient	0.531 ***	**Saudi Arabia**	Coefficient	0.306 **
	White's adjusted SE	0.187		White's adjusted SE	0.125
	Newey-West's adjusted SE	0.198		Newey-West's adjusted SE	0.138
China	Coefficient	0.442 ***	**Singapore**	Coefficient	1.096 ***
	White's adjusted SE	0.156		White's adjusted SE	0.243
	Newey-West's adjusted SE	0.136		Newey-West's adjusted SE	0.274
Euro	Coefficient	0.765 ***	**South Africa**	Coefficient	0.713 ***
	White's adjusted SE	0.106		White's adjusted SE	0.185
	Newey-West's adjusted SE	0.132		Newey-West's adjusted SE	0.186
India	Coefficient	1.050 **	**Sweden**	Coefficient	0.939 ***
	White's adjusted SE	0.463		White's adjusted SE	0.146
	Newey-West's adjusted SE	0.503		Newey-West's adjusted SE	0.193
Indonesia	Coefficient	0.659 **	**Switzerland**	Coefficient	0.599 ***
	White's adjusted SE	0.263		White's adjusted SE	0.055
	Newey-West's adjusted SE	0.266		Newey-West's adjusted SE	0.047
Iran	Coefficient	0.028	**Thailand**	Coefficient	0.509 ***
	White's adjusted SE	0.281		White's adjusted SE	0.197
	Newey-West's adjusted SE	0.248		Newey-West's adjusted SE	0.186
Japan	Coefficient	0.501 ***	**Turkey**	Coefficient	1.154 ***
	White's adjusted SE	0.067		White's adjusted SE	0.289
	Newey-West's adjusted SE	0.064		Newey-West's adjusted SE	0.338
Korea	Coefficient	0.180	**UK**	Coefficient	1.228 ***
	White's adjusted SE	0.116		White's adjusted SE	0.257
	Newey-West's adjusted SE	0.113		Newey-West's adjusted SE	0.292
Malyasia	Coefficient		**USA**	Coefficient	0.545 ***
	White's adjusted SE			White's adjusted SE	0.083
	Newey-West's adjusted SE			Newey-West's adjusted SE	0.076
Mexico	Coefficient	0.754 ***	**Venezuela**	Coefficient	0.470 **
	White's adjusted SE	0.200		White's adjusted SE	0.160
	Newey-West's adjusted SE	0.232		Newey-West's adjusted SE	0.19947
New Zealand	Coefficient	0.570 **			
	White's adjusted SE	0.160			
	Newey-West's adjusted SE	0.193			

Note: *, **, and *** indicate that the estimated coefficient is statistically significant at the 10%, 5% and 1% levels, respectively. Y_{it} = real GDP for country i at time t. The impact elasticities are the coefficients and are reported along with their corresponding White's and Newey-West standard errors.

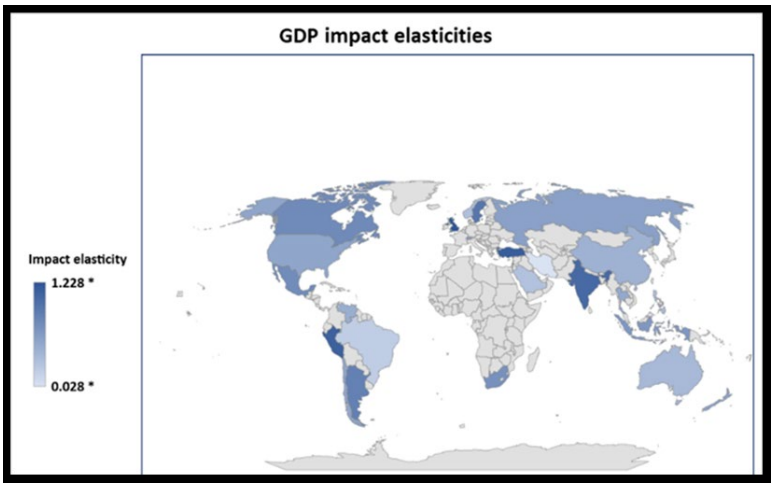
Source: Considine *et al.* (2023a).

Figure 1 on the next page shows a heat map, with dark blue representing the highest value for impact elasticity and lighter blue shades reflecting the smaller values. As expected, the majority of the impact

elasticities related to foreign GPD are statistically significant and positive. The countries with the highest elasticities – over 1% include the U.K. (1.23%), Turkey (1.15%), Singapore (1.10%), and India (1.05%) – all statistically significant relations. The income elasticity for the euro area is approximately 0.77%, suggesting that a 1% increase in foreign GDP results in a 0.77% change in real GDP in the Euro area. The real income elasticities for the developed countries are all similar, or slightly lower as is the case for the U.S. (0.54%), Canada (0.76%), and Norway (0.31%). China, Japan, and Korea are considerably lower at (0.44%), (0.05%) and (0.18%), respectively.

The "foreign" income elasticities for the Middle Eastern nations included in the model, Saudi Arabia (0.31%) and Iran (0.02%), are considerably lower than the results reported in the euro area and developed economies, suggesting some degree of isolation from foreign linkages. This can be a double-edged sword, beneficial in times of global recession, and not necessarily beneficial when the global economy is on the rise.

Figure 1
Heat Map of Country-Specific International Linkages



Note: The contemporary impact elasticity is defined as the percentage change in Saudi Arabian real GDP in response to a 1% change in its corresponding foreign variable in the current quarter (Dees *et al.*, 2007; Cao *et al.*, 2017; Chudik and Pesaran, 2016). The elasticities are reported only for those 36 countries included in our GVAR model. The non-colored countries have not been considered in the assessment.

Source: Considine *et al.* (2023a).

Pair-Wise Cross-Section Correlations: GDP

The ability of the GVAR model to capture the complex relationships between the variables rests on the proposition that the foreign variables have been successful at capturing the common global factors in the economy. This is reflected in the pair-wise cross-section correlations of the domestic variables with their foreign counterparts, the first differences and the residuals of the VARX* models; see Table 2 and Figure 2 on the following two pages. A successful modelling effort will result in low pair-wise correlations with the

residuals of the error corrected VECMX* models. See Textbox A on the next page: "Shocks to Country-Specific Models."

As expected, the real GDP correlations are high for the levels of the endogenous variables and fall when first differences and residuals are considered. The level of real GDP shows the highest levels of cross-section correlations, which range between 0.84 and 0.91 for all countries except Russia (0.38) and Venezuela (-0.47). The pair-wise cross-section correlations between real GDP in Saudi Arabia and its foreign counterparts is 0.87, suggesting that movements in real GDP in Saudi Arabia can be captured or explained by global factors, including recession and strong global economic growth in the rest of the world. Countries such as Russia and Venezuela are effectively isolated from the global economic system.

Table 2

Average Pair-Wise Cross-Section Correlations of Country-Specific Real GDP with Foreign Counterparts and Associated Model's Residuals

	Y_{it}		
	Levels	First differences	VECMX* residuals
Argentina	0.8740	0.1126	0.0019
Australia	0.9076	0.1962	0.0660
Brazil	0.9007	0.1110	0.0237
Canada	0.9046	0.2713	0.0075
China	0.9096	0.1499	-0.0729
Chile	0.8995	0.1628	0.0069
Euro	0.8925	0.3225	0.0160
India	0.9033	0.1895	0.0326
Indonesia	0.8950	0.0984	0.0158
Iran	0.8955	-0.0661	-0.0723
Japan	0.8404	0.1961	0.0253
Korea	0.8907	0.1562	0.0283
Malaysia	0.9014	0.1827	0.0097
Mexico	0.9036	0.2327	0.0376
Norway	0.8960	0.1283	-0.0085
New Zealand	0.9008	0.2207	0.0813
Peru	0.8604	0.0740	0.0251
Philippines	0.8849	0.1437	0.0469
Russia	0.3846	0.0684	0.0023
South Africa	0.8959	0.2830	0.0755
Saudi Arabia	0.8735	0.0641	0.0095
Singapore	0.9023	0.2488	-0.0027
Sweden	0.9045	0.2294	0.0277
Switzerland	0.9062	0.2490	0.0051
Thailand	0.8846	0.1622	0.0069
Turkey	0.9052	0.1601	-0.0043
UK	0.8982	0.2810	0.0308
USA	0.8999	0.2679	-0.0047
Venezuela	-0.4659	0.1036	0.0140

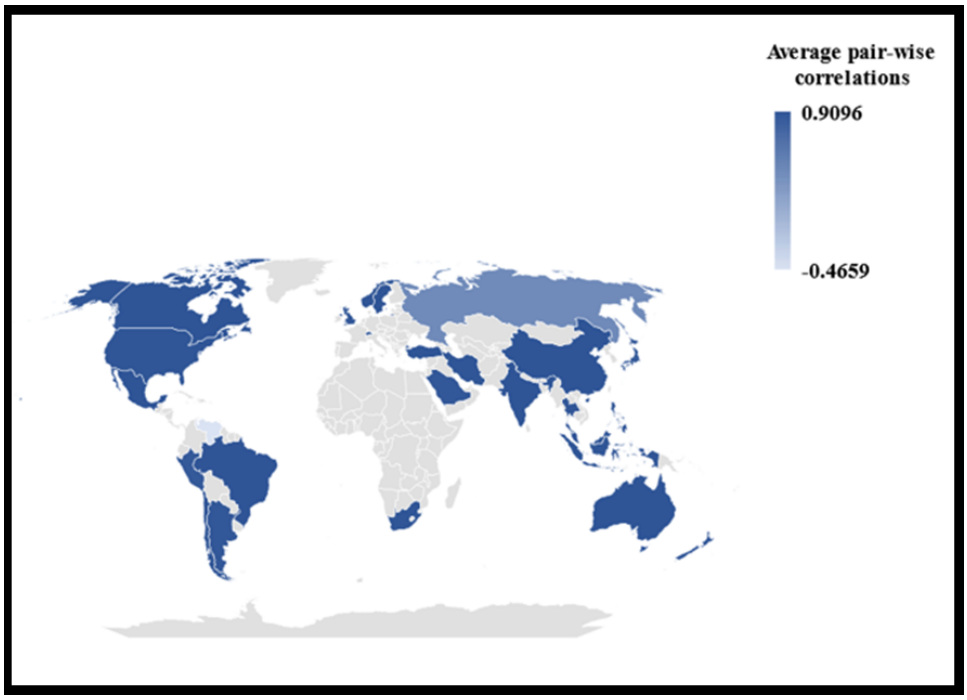
Note: Y_{it} = real GDP for country i at time t.

Source: Considine *et al.* (2023a).

Textbox A: Shocks to Country-Specific Models

In the GVAR framework, an "idiosyncratic" shock to the country-specific models is assumed to be weakly correlated across countries, $cov(x_{ij}^{*}, u_{it}) \rightarrow 0, as\ N \rightarrow \infty$. Country-specific models are conditioned on weakly exogenous foreign variables. These weakly exogenous foreign variables, in turn, serve as proxies for the common global factors that affect the system. Following Chudik and Pesaran (2016), the remaining shocks across countries should be modest and reflect only residual consideration such as the spillover effects of monetary and fiscal policy, and trade movements. During the estimation process, we test the proposition that the foreign variables have been successful at capturing common global factors and, as a result, have reduced the cross-section correlation of the variables. To accomplish this, following Dees *et al.* (2007) we compute the average pair-wise correlations for the levels and first differences of the endogenous variables and the associated residuals for the sample period, 1979 to 2022.

Figure 2
Average Pair-Wise Cross-Section Correlations of Domestic Variables and Their Foreign Counterparts



Source: Considine *et al.* (2023a).

Pair-Wise Cross-Section Correlations: Oil Production

Table 3 and Figure 3 on the next two pages illustrate the pair-wise cross-section correlations of the domestic variables with their foreign counterparts for crude oil production. In other words, this measure shows whether a country's oil supply tends to move in the same direction as the foreign variable oil supply from the rest of the world. The results for oil production measured in terms of pairwise correlation coefficients are considerably lower and more diverse than those for GDP, with pair-wise correlations for levels averaging only (-0.02), with a range of (-0.26) in the U.S.A. and Russia, to (0.17) in Iran and Norway. The negative cross-section correlations in Russia and the United States can be explained by the aggressive

development of both technical shale reserves and production in both countries, and in the case of Russia, OPEC+ measures to stabilize world oil markets[7] (Mikkelsen, 2023). The level pair-wise correlations for Saudi Arabia crude oil production are (0.07), falling slightly to (0.05) for first differences, and (0.06) for the residuals, and reflect the role of Saudi Arabia in stabilizing world oil markets.

When the correlations are compared to levels estimated for 2013 (a year characterized by a tight oil market) these values change considerably. For example, the range of values has dropped from 0.24 (Norway) to -0.39 (Russia) in 2013 to 0.17 (Norway) to -0.26 (Russia) reported in the second quarter of 2022. Evidence suggests that the world oil market has become less predictable over the last decade, despite the best efforts of OPEC and OPEC+. The increased volatility is due to the magnitude of macroeconomic and geopolitical shocks, such as COVID-19, and war in the Ukraine. The correlation of domestic oil supply to its foreign counterparts is falling significantly for every country except Russia and the United States. While Russia is still an outlier and negatively correlated with the rest of the oil-producing countries, the magnitude of the correlation coefficient has fallen by 0.12.

Table 3

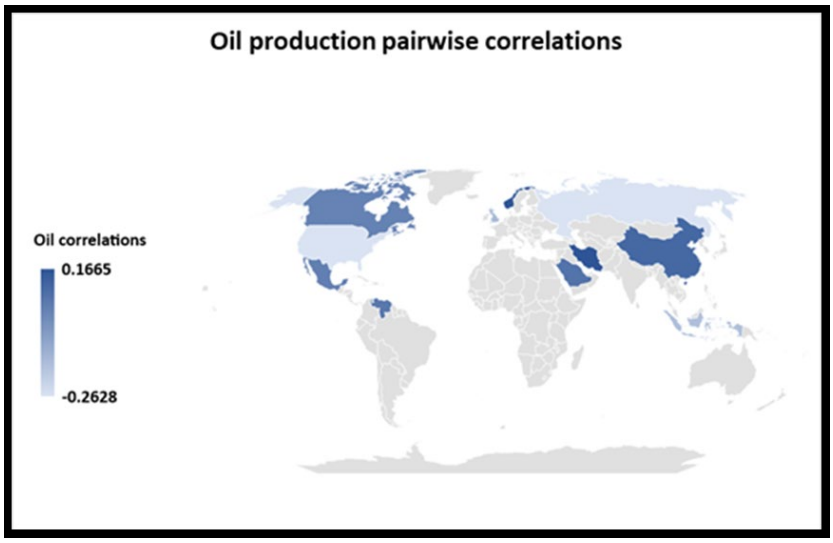
Average Pair-Wise Cross-Section Correlations of Domestic Oil Production with Foreign Counterparts and Associated Model's Residuals

	Qs_{it}^{0}				Qs_{it}^{0}		
2022	Levels	First differences	VECMX* residuals	2013	Levels	First differences	VECMX* residuals
Canada	0.0285	0.0725	0.0368	Canada	0.1179	0.0495	0.0306
China	0.1075	-0.0252	-0.0444	China	0.1567	-0.0361	-0.0432
Indonesia	-0.1576	0.0235	0.0232	Indonesia	-0.1576	0.0189	-0.0104
Iran	0.1665	-0.0030	0.0086	Iran	0.2055	-0.0081	0.0069
Mexico	0.0362	0.0449	0.0451	Mexico	0.1771	0.0377	0.0448
Norway	0.1662	0.0296	0.0672	Norway	0.2415	0.0078	0.0133
Russia	-0.2628	0.0444	0.0158	Russia	-0.3860	-0.0537	-0.0110
Saudi Arabia	0.0724	0.0508	0.0634	Saudi Arabia	0.1111	0.0418	0.0149
UK	-0.1378	0.0630	0.0648	UK	-0.0987	0.0496	0.0151
USA	-0.2618	0.0597	0.0618	USA	-0.3881	0.0076	0.0009
Venezuela	0.0596	0.0916	0.0479	Venezuela	0.2093	0.0266	0.0216

Note: Qs_{it}^{o} = oil production in country i at time t.

Source: Considine *et al.* (2023a).

Figure 3
Average Pair-Wise Cross-Section Correlations of Domestic Oil Production and Their Foreign Counterparts



Source: Considine *et al.* (2023a).

Conclusions

Despite the increased pace of economic diversification in Saudi Arabia, and its integration into the world economic scene, the country remains less affected by global macroeconomic dynamics than most of the developed nations and regional economic powerhouses. The impact elasticity of an increase in foreign GDP on its domestic counterparts is lower for Saudi Arabia (0.3%) than the Euro area (0.75%), India (1.05%), and Turkey (1.15%). This insulation may prove to be beneficial in the times of global macroeconomic crises.

The level of real GDP displays the highest levels of international cross-section correlations, which range between 0.84 and 0.91 for all of the countries except Russia (0.38) and Venezuela (-0.47). Saudi Arabia – at 0.87 – falls in the middle of this range. When first differences are considered, the focus shifts to the correlation between movements in the variables. In this case, Saudi Arabia's correlation coefficient falls to 0.06 – well below the average for the sample countries in this study.

In the oil sector, the cross-country correlations are relatively weak and would appear to be weaker in loose market conditions with the correlation levels falling gradually over the past decade. In Saudi Arabia less than 10% of the changes in oil production are contingent on and can be explained by changes in oil production from the rest of the world. These results suggest that the global oil industry – more than other sectors – has been affected by deglobalization and the large macroeconomic / geopolitical shocks of the previous decade. In international oil markets, cross-country correlations have been falling steadily despite the stabilization efforts of OPEC and OPEC+ member countries. If history can be our guide, the winners and losers of the next oil shock have already been clearly defined!

Endnotes

1 The low correlations in the oil producing sector are due to the diverse geological and geopolitical nature of world oil reserves, and production facilities. Loose market conditions add an additional cushion of high inventories.

2 Friendshoring refers to countries rerouting supply chains to friendly and politically "safe" countries in an attempt to mitigate supply risk.

3 In December 2022, Saudi Arabia's Public Investment Fund (PIF) announced the acquisition of 9.5% of Skyborn Renewables, a German offshore wind developer. Masdar and Saudi Arabia's ACWA Power are investing in a number of solar and wind projects across the Middle East and North Africa (Dourian, 2023; Mammoser, 2022).

4 Results of the statistical tests are available on request.

5 The term foreign GDP that is specific to Saudi Arabia is defined as a weighted cross section average of real GDP in all of the countries included in the GVAR and listed in Table 1. The weights are calculated using detailed data on bilateral trade flow data.

6 The elasticity of income in a specific country with respect to a change in aggregate foreign income.

7 Russia boosted Bazhenov tight oil output by 70% in 2020.

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Dr. Considine has worked with numerous international energy companies, including Ecopetrol, TransCanada Pipelines, Westcoast Energy, Coastal Corporation, Duke Energy and the ANR Pipeline Company. She is currently the chief editor of *Energy Politics*, an energy newsletter investigating commercial strategies and strategic planning in the global energy industry. Dr. Considine is a former member of the Board of Directors for Canada Post. She is a founding member of several initiatives to promote Scottish-Canadian relations, including the Canadian Friends of Scotland.

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Philipp Galkin is a visiting researcher at KAPSARC, working on the economic and policy aspects of energy supply and trade. Galkin's work at KAPSARC includes evaluating the effect of preferential trade agreements on energy flows, the 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.

Assessing Impacts of Global Economic Dynamics on the Saudi Economy and Oil Production: A GVAR Analysis

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Emre Hatipoglu is a fellow in KAPSARC's Oil and Gas program. His research connects political science to the study of energy markets, focusing on geopolitics and the international political economy. Before joining KAPSARC, he was associate professor at the Faculty of Arts and Social Sciences, Sabanci University, Istanbul, where he was the program coordinator of the International Studies (B.A.), Conflict Analysis and Resolution (M.A..), and European Studies (M.A.) programs between 2013 and 2017.

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Abdullah Al Dayel is a senior research analyst in the Markets and Industrial Development program with a focus on oil markets and energy policies. He holds a Bachelor of Science in Petroleum Engineering from the King Fahd University of Petroleum and Minerals.

Appendix A:
KAPSARC's Oil Market Rebalancing Project

The purpose of this project is to develop an analytical framework to analyze shocks to world oil and inventory markets. The model can facilitate an investigation of the economic implications of country- and region-specific oil and inventory disruptions, such as economic sanctions, wars, financial crises, natural disasters, and monetary and fiscal policy changes. The model proposed for the World Oil and Inventory Study is based on traditional Global Vector Autoregressive (GVAR) models.

Two characteristics make a GVAR-based approach particularly well suited to this research. First, it is designed to account for the interactions between many countries, each with its own political and legislative system. This is crucial, as the effects of severe shocks and global imbalances cannot be contained within one country or region. Second, GVAR can model world oil supplies and inventories jointly with key macroeconomic variables, including short- and long-term interest rates, inflation, equity prices and real gross domestic product (GDP). The framework therefore facilitates an investigation of the effects of country- and region-specific oil shocks on GDP, inflation, interest rates, inventories, exchange rates and equity prices globally.

The model developed for this project, the KAPSARC Global Oil Vector Autoregression Model (GOVAR) represents a slight variation to this approach. In the case of GOVAR, the global oil market is modeled separately, by means of a single price equation that accounts for global supply and demand conditions. Global oil supplies are included in each country-specific model, reflecting global oil supplies for all major oil producing countries. As a result, the combined system-wide model can estimate the impact of country-specific oil shocks on the global economy and the related implications for global financial markets, equity prices, interest rates and oil prices.

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