مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

Determinants of Saudi Arabia's International Competitiveness: Historical Analysis and Policy Simulations

Fakhri J. Hasanov and Noha H. A. Razek

June 2023
Doi: 10.30573/KS--2023-DP14

Acknowledgments

We would like to thank the researchers from the Saudi Central Bank for their comments and suggestions. We are also grateful to Carlo Andrea Bollino and Fatih Yilmaz for their referee recommendations. We accept sole responsibility for any errors and omissions. The views expressed in this paper are the authors' and do not necessarily represent the views of their affiliated institutions.

About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

This publication is also available in Arabic.

Legal Notice

Key Points

Saudi Vision 2030 aims to improve Saudi Arabia's ranking on the Global Competitiveness Index from 25 in 2015–2016 to within the top 10 by 2030. It also strives to increase the share of non-oil exports in non-oil GDP from 16% in 2016 to 50% by 2030. To achieve these goals, decision-making process should be better informed about the driving forces of Saudi Arabia's competitiveness. To this end, we consider the real effective exchange rate (REER) as a measure of external price competitiveness, as it captures domestic and global changes in prices. We then examine the REER using a two-stage modeling framework: First, we estimate the REER equation, which allows us to assess the impacts of theoretically formulated determinants on competitiveness. Second, we extend the KAPSARC Global Energy Macroeconometric Model with the estimated equation, which provides a framework for simulating impacts of the theoretically formulated determinants and other variables relevant to policymakers regarding the country's competitiveness. The framework also allows us to account for feedback loops. We conduct a policy scenario analysis to quantify the competitiveness effects of the Public Investment Fund's (PIF) new strategy for 2021–2025.

The main findings can be summarized as follows:

- Saudi external price competitiveness has mainly been shaped by relative productivity in the non-oil sector, followed by government consumption, relative productivity of the oil sector and net foreign assets (NFA).

- Historical misalignment analysis indicates that deviation of the REER from its equilibrium values (i.e., appreciation and depreciation) have remained within an acceptable range.

- Additional governmental investments in the economy through the PIF new strategy will increase productivity in the non-oil sector, and Saudi Arabia's external price competitiveness will improve as a result.

Several policy insights can be derived from this research.

- Initiatives that can boost future productivity should be implemented. The PIF investments are worth emphasizing in this regard.

- An increase in government consumption can raise both the observed level and competitiveness of the REER. The extent to which this increase may undermine competitiveness depends on whether the observed level exceeds the competitiveness level. Therefore, policymakers should be regularly informed about misalignments in the REER. In addition, government consumption and public investment should consider substituting imports with locally produced goods and services to avoid any potential deterioration of the trade balance. Local content development would also help diversify the Saudi economy.

- Attracting more foreign investment and other assets from the rest of the world may lead to technological development and improvement in the business environment as well as the economic, financial and social infrastructure. It may also lead to a reduction in the NFA position, causing the REER of the riyal to appreciate. That is, foreign investment may increase competitiveness. However, if such appreciation causes the observed values of the REER to exceed its competitiveness values, competitiveness may worsen. This, in turn, necessitates regularly monitoring misalignment and updating the decision-making process accordingly.

Introduction

The Kingdom of Saudi Arabia's strategic plan Saudi Vision 2030 outlines targets that it aims to achieve by the end of the decade. One of its key goals is to improve the Kingdom's ranking in the Global Competitiveness Index from 25 in 2015–2016 to within the top 10 by 2030. Saudi Vision 2030 also targets an increase in the share of non-oil exports in non-oil gross domestic product (GDP) from 16% in 2016 to 50% by 2030. Achieving these strategic targets will require improvements in Saudi Arabia's competitiveness. To help policymakers better understand the driving forces of external competitiveness, we employ a novel modeling framework to investigate the main determinants of the real effective exchange rate (REER) as a measure of external price competitiveness.

The REER, which is based on the Balassa-Samuelson concept and encompasses a ratio of domestic and foreign prices, is a widely used measure of competitiveness (see Balassa [1964]; European Commission [2002]; IMF [n.d.]; Nagayasu [2017]; Peters [2010]; Samuelson [1964]; UNCTAD [2012]). Both appreciation and depreciation of the REER beyond a desired equilibrium may harm economic growth via different channels. For example, the depreciation of the REER may induce exports and discourage imports, and vice versa in the case of any appreciation (Rodrik 2007). Therefore, determining an equilibrium path for the REER that accounts for how it is shaped by its driving forces has become an important research focus. Identifying this path can inform policymaking to improve a country's competitiveness. Existing empirical studies do not provide sufficient insights into the main determinants of Saudi REER-based competitiveness because very few researchers have investigated the topic. In those few studies, oil prices were considered the only driver of REER, ignoring other key fundamentals. Moreover, existing studies do not provide a holistic view, as they are based on a single equation—that is, a partial equilibrium framework. Only Razek and McQuinn (2021) applied a vector error correction model (VECM) to estimate the magnitude of currency misalignment between observed REER and estimated long-term equilibrium REER as an external competitiveness indicator. While still a partial equilibrium model, this is better than a single-equation-based analysis.

Therefore, the objective of this study is to develop a novel modeling framework for REER-based competitiveness to support the decision-making process.[1] This modeling framework enables us to analyze the Saudi REER as a measure of international price competitiveness and determine its equilibrium path both historically (1980–2018) and in the near future (up to 2025). As a conceptual framework, we use the behavioral equilibrium exchange rate (BEER) approach because it can empirically link the REER, as a measure of competitiveness, to domestic (including country-specific) and external fundamentals. Such fundamentals include productivity, net foreign assets (NFA), government spending and other macroeconomic indicators (see, e.g., Baffes, Elbadawi, and O'Connell [1999]; Clark [1997]; Clark and MacDonald [1999, 2004]). We conduct a cointegration analysis, as it addresses stochastic properties of the considered variables and hence eliminates concerns regarding spurious results (see, e.g., Engle and Granger [1987]; Granger and Newbold [1974]). Our analysis yields policy insights that might help decision-makers develop relevant measures to further improve Saudi competitiveness, and thereby achieve the above-mentioned goals of Saudi Vision 2030.

Our two-stage modeling framework constitutes a methodological contribution to the REER literature. In the first stage, we specify and estimate the equations that link the REER to its theoretically articulated and country-specific determinants. This enables us to examine how these determinants have shaped competitiveness historically (1980–2018). In the second stage, we incorporate the estimated REER equation into the general/full equilibrium KAPSARC Global Energy Macroeconometric Model (KGEMM; see Hasanov et al. [2020, 2022]). Doing so enables us to assess how determinants included in the REER equation as well as other policy-relevant variables affect Saudi competitiveness in the near future (up to 2025). Thus, the policy recommendations of this study are not simply derived from a single-equation estimation framework (i.e., the partial equilibrium used in previous studies). They are also based on simulation analyses using a macroeconometric model (i.e., KGEMM). A macroeconometric model, as a full/general equilibrium framework, has two main advantages over a single-equation or other partial-equilibrium frameworks. It allows for feedback loops, and it assesses the effects of additional variables (including policy levers) not included in a single equation (e.g., Elshurafa et al. [2022]; Bandara [1991]; Ballantyne et al. [2020]; Beenstock and Dalziel [1986]; Cusbert and Kendall [2018]; Hasanov [2019]; Hasanov, Javid, and Joutz [2021]). For example, in the single-equation analyses of REER conducted in many previous studies, relative productivity is treated as an exogenous variable. However, given its nature, this variable should be treated as endogenous. To this end, macroeconomic models provide comprehensive representations of processes, and thus deliver broader information content compared to single-equation and other partial equilibrium frameworks.

We also make several contributions to the literature on Saudi competitiveness. First, unlike many previous studies, we do not limit ourselves to oil prices. We analyze a broader set of REER determinants, including relative productivity, net foreign assets and government consumption. This eliminates the omitted variable bias issue while providing broader information about the driving forces of Saudi competitiveness. Additionally, we examine the effects of relative productivity in the non-oil and oil sectors separately. Development of the non-oil sector is the cornerstone of the economic diversification plan in Saudi Vision 2030. Hence, different aspects of this development, including productivity, should be considered. Second, to obtain robust empirical findings and provide well-grounded policy recommendations, we perform robustness checks. We do so not only by employing various estimation and testing methods, but also by considering alternative specifications of the REER used in the literature. Third, we do not just estimate the historical relationship between REER-based competitiveness and its driving factors; we also provide an outlook for Saudi price competitiveness through 2025 using policy scenario analysis. The policy analysis examines the likely economic outcomes of investing in the non-oil sector to improve domestic productivity in the Kingdom by building on the recent work of Razek and McQuinn (2021). Fourth, we assess misalignments of the Saudi REER for both in-sample and out-of-sample periods, thereby providing a clear picture of the Kingdom's competitiveness and the necessary adjustments, which yields useful information for decision making processes.

The rest of this paper is organized as follows. In section 2, we review relevant literature, before discussing theoretical considerations and the determinants of Saudi Arabia's competitiveness in section 3. We present our data and econometric methods in sections 4 and 5, respectively. We present the results of our empirical analysis in section 6 and discuss our empirical findings in section 7. In section 8, we present our policy simulation analysis, before offering some concluding remarks and policy insights in section 9.

Literature Review

Studies on the Saudi REER as a measure of price competitiveness and the effects of misalignment are scant. Suliman and Abid (2020), Aleisa and Dibooĝlu (2002), Habib and Kalamova (2007) and Altarturi et al. (2016)[2] quantitatively modeled determinants of Saudi Arabian riyal (SAR) movements. However, they studied neither Saudi Arabia's currency misalignment nor international competitiveness. Couharde et al. (2018), Grekou (2018), Mozayani and Parvizi (2016), Coudert, Cécile and Mignon (2008) and Coudert and Couharde (2008) applied panel data analysis to groups of countries, including Saudi Arabia, over different time periods. These studies either did not discuss the results for Saudi Arabia in detail or warned readers to interpret the results with caution. To our knowledge, only Razek and McQuinn (2021) have studied Saudi Arabia's currency misalignment and international competitiveness. Below is a review of the limited literature on Saudi Arabia's exchange rate and currency misalignment as a measure of international competitiveness.

Using monthly data between 1986 and 2019, Suliman and Abid (2020) employed an error correction model (ECM) to examine the short- and long-term effects of the two-way relationships between the nominal West Texas Intermediate (WTI) oil price and the Saudi REER. They did not include other variables in the model. Their results confirm cointegration of the two variables and show causality from oil prices to the REER in the short-term. However, they show a bi-directional relationship in the long run, as appreciation of the Saudi currency causes a relative increase in oil demand, and accordingly an increase in oil price.

Aleisa and Dibooĝlu (2002) employed a vector autoregressive (VAR) model, assuming long-term neutrality of nominal shocks, to examine the determinants of real exchange rate movements in the Kingdom. They used first-differenced values for the consumer price index (CPI), REER, oil production, and real oil price in domestic currency from February 1980 to February 2000. They found that real shocks dominate nominal shocks and that oil production, rather than oil price shocks, plays a significant role in explaining exchange rate movements. They argued that oil production stabilization would result in exchange rate stabilization. We think that this study has some weaknesses. First, the authors concluded that the variables in their analysis were I(1). However, they did not test whether the variables were cointegrated. If the variables are cointegrated and estimations do not account for this, the econometric results can be misleading because of the omitted variable bias issue. The authors also stated that they used the Akaike information criterion (AIC) to select the optimal lag in the augmented Dickey-Fuller (ADF) test. However, they used likelihood ratio testing for their VARs without justifying why they switched from one lag selection information criterion to another. Additionally, they did not include graphs of the variables in the study to provide readers with more information, such as how the variables' time profiles evolved, how closely they moved together and whether they exhibited a leading or lagging effect. Lastly, they stated that they used seasonally unadjusted monthly data, but it is not clear how they dealt with seasonality; that is, whether they seasonally adjusted the variables before using them or used seasonal dummy variables to capture seasonal patterns that could affect their results.

Habib and Kalamova (2007) generated a REER series for Saudi Arabia and applied a time series analysis to examine the impact of the real price of oil on Saudi real exchange rate movements. Their results showed that the real price of oil has no impact on the real exchange rate. They attributed the absence of any relationship between the exchange rate and oil price in Saudi Arabia to price subsidies, flexible labor markets, accumulation of NFA and the sterilization of oil revenues. They also stated that because the U.S. is an important trade partner, movements of the nominal effective exchange rate follow those of the U.S. dollar. Hence, they reflect fluctuations against the currencies of trade partners. Although we appreciate that this is one of very few studies to investigate the Saudi REER, we believe that this study would have benefitted if Habib and Kalamova (2007) had addressed the following issues. First, they did not explain why they utilized the Dubai oil price instead of the Arabian crude oil price, which is more relevant for Saudi Arabia. Second, the authors stated in footnote 24 that there was no cointegration between the REER and the real oil price in the full sample, 1980–2006, but there would be cointegration if the sample was truncated to start in 2001. This finding seems to contradict their Figure 2-C, which shows that since 2001, the REER and the real oil price have moved in opposite directions; thus, it is hard to believe that they share a common trend. Third, it is possible that the authors did not find a long-term relationship between the REER and oil prices because they used a bivariate specification in the cointegration analysis. Theoretically, the REER is not only driven by terms of trade (TOT), proxied by oil prices in that study, but also by other fundamentals, including productivity, NFA and government spending. Hence, the bivariate specification is subject to an omitted variable bias problem. This bivariate specification problem is significantly present in the short-term estimation, such that variation in the growth rate of the real oil price and its two lags can only explain 3% of the variation in the REER growth rate. This means that approximately 97% of information is missing due to the omission of relevant variables in the analysis. The authors stated that they could not find NFA for the full sample or proper GDP and employment data for Saudi Arabia to construct the productivity variable. However, they could have used a ratio of non-tradable price to tradable price as a measure of productivity. Empirical analyses of the REER frequently use this ratio. Finally, it would provide more clarity for readers if the authors discussed how they decided on the maximum number of lags and how they ended up with two lags in their short-term analysis (see Habib and Kalamova [2007], 23, Table 6).

Applying a wavelet methodology to daily data from Organization of Petroleum Exporting Countries (OPEC) members, Altarturi et al. (2016) conducted a correlation analysis between the growth rates of oil prices and nominal effective exchange rates. They found that exchange rate changes lag behind oil price movements in countries that peg their currency to the U.S. dollar. Although they emphasized the importance of taking oil price fluctuations into account when formulating exchange rate policies, they did not consider other theoretically articulated determinants of exchange rates. Additionally, they used daily data to conduct the correlation analysis, which is unusual and too noisy to investigate the macroeconomic aspects of exchange rates.

Couharde et al. (2018) used panel data for 182 countries and applied the BEER approach[3] to estimate equilibrium REERs from 1973 to 2016 and currency misalignments during 2015–2016. Their sample included Saudi data and accounted for NFA, TOT and the ratio of real GDP per capita relative to trade partners (to proxy the Balassa-Samuelson impact). Grekou (2018) expanded on Couharde et al.'s (2018) study by examining similar data as well as trade openness for 186 countries, including Saudi Arabia, from 1973 to 2017. Nevertheless, they advised that the results for Saudi Arabia should be interpreted with caution. Coudert and Couharde

(2008) used panel data from 1974 to 2004 for 128 countries, including Saudi Arabia, to estimate misalignments using the BEER approach; however, they discussed the results for the full sample without providing details on Saudi Arabia's case. Mozayani and Parvizi (2016) used panel data for 11 OPEC countries from 1990 to 2012 to estimate currency misalignment. They discussed the results for the full sample with a focus on Iran and without details on the Saudi case.

Whereas Couharde et al. (2018), Grekou (2018), Coudert and Couharde (2008) and Mozayani and Parvizi (2016) used panel data to estimate currency misalignments for a set of countries that include Saudi Arabia, Razek and McQuinn (2021) applied time series analysis to explore the Saudi case. Razek and McQuinn (2021) used data on Saudi Arabia from 1986 to 2019. Following Clark and MacDonald (1999, 2004), Eckstein and Friedman (2011), Couharde et al. (2018), Grekou (2018), Giordano (2019) and Fidora, Giordano, and Schmitz (2021), they applied a VECM model and the BEER approach to estimate the magnitude of currency misalignment between the observed REER and estimated long-term equilibrium REER as an indicator of external competitiveness. They employed Saudi Arabia's international reserves to capture the country's productivity as well as its ability to borrow. Additionally, they used the oil market risk premium and global demand for oil to capture the role of oil as a commodity and financial asset. They also considered military expenditures and government expenditures, which are mainly directed to non-tradables. One of Razek and McQuinn's (2021) main findings is that there is room to improve Saudi Arabia's domestic productivity. In this study, we build on Razek and McQuinn's (2021) work by examining the likely economic outcomes of investing in the non-oil sector to improve domestic productivity in the Kingdom. We include government consumption in our econometric analysis and government investments by the Public Investment Fund (PIF) in our model simulations.

Like Razek and McQuinn (2021), Suliman and Abid (2020), Habib and Kalamova (2007) and Aleisa and Dibooĝlu (2002), we conduct a time series analysis in this study. Razek and McQuinn (2021) used the oil market risk premium, Suliman and Abid (2020) used WTI oil prices and Habib and Kalamova (2007) used Dubai oil prices. It is not clear to us which oil price measure Aleisa and Dibooĝlu (2002) utilized. We employ a government expenditure variable rather than an oil price variable because the latter affects the Saudi REER indirectly through government expenditure. Habib and Kalamova (2007) justified not including a productivity variable because of the lack of quarterly data on GDP. We extend on Razek and McQuinn (2021), who accounted for productivity in the tradable and non-tradable goods and services sectors by constructing relative productivity measures for the non-oil and oil sectors to account for their impacts on competitiveness separately. This is because the economic policy agenda outlined in Saudi Vision 2030 is focused mainly on the development of the non-oil sector. We employ the KGEMM model to conduct policy simulations.

Theoretical Background and Determinants of Saudi Arabia's REER

Theoretical Background

The REER is an aggregate price competitiveness indicator that reflects the productivity and efficiency of production, distribution and marketing chains as well as exchange rates between a commodity's importer and exporter (Leichter, Mocci, and Pozzuoli 2010). Peters (2010), Nagayasu (2017), the European Commission (2002) and international organizations, such as the International Monetary Fund (IMF), World Bank and United Nations Conference on Trade and Development (UNCTAD), have discussed price competitiveness as a macroeconomic term measured by the REER. UNCTAD (2012) stated that the REER remains a superior indicator of a country's competitiveness. Comunale and Mongelli (2020) and Giordano (2019) used the REER as a proxy for price competitiveness, and Razek and McQuinn (2021) discussed the appropriateness of using the REER rather than the Global Competitiveness Index (GCI). Hence, we consider the REER to be a measure of Saudi Arabia's price competitiveness.

The BEER approach is widely used to estimate the REER and calculate currency misalignments to derive a measure of external competitiveness. We chose the BEER framework because it can be empirically linked to domestic and external fundamentals such as terms of productivity, NFA, TOT, openness, government spending and other macroeconomic fundamentals (see, e.g., Baffes, Elbadawi, and O'Connell [1999]; Clark [1994]; Clark and MacDonald [1998, 2000]). Put differently, the BEER framework enables a country's global competitiveness to be examined as a function of domestic and global driving forces (see, e.g., Lauro and Schmitz [2013]). Additionally, the BEER framework enables not only theoretically predicted factors but also country-specific factors (e.g., oil prices in the case of oil-dependent economies) to be considered in a competitiveness analysis.

Building on Clark (1994), Baffes, Elbadawi, and O'Connell (1999) and Clark and MacDonald (1999, 2004), this approach is based on the theory of uncovered interest rate parity (UIP). Estimates are based on the assumed realization of the potential long-run relationship between exchange rates and relevant economic fundamentals. The UIP concept is represented by equation (1):

$$q_t = E_t(q_{t+i}) - (R_t - R_t^*) \qquad (1)$$

where q_t and $E_t(q_{t+i})$ are the observed and expected real exchange rate at time t, and R_t and R_t^* are the domestic and foreign real interest rates. According to this approach, $E_t(q_{t+i})$ is merely determined by the economic fundamentals (e.g., productivity, NFA and government consumption), TOT and openness in the long run. Hence, the REER is modeled as a function of these economic fundamentals in the long term and as a function of the interest rate differential in the short term.

Razek and McQuinn (2021), Giordano (2019) and Fidora, Giordano, and Schmitz (2021) discussed different approaches for modeling currency misalignments and the advantages of the BEER approach in more detail. Giordano (2019) and Fidora, Giordano, and Schmitz (2021) provided a survey of the explanatory variables in the literature on the BEER approach and recommended a general-to-specific approach to test for potential determinants and derive a model specification that fits the economy of interest. In other words, one of the advantages of the BEER approach over other approaches is that it can be modified to consider country-specific characteristics, which are believed to play important roles in shaping the equilibrium level of the REER in a given economy (see, e.g., Alshehabi and Ding [2008]).

Determinants and Model of the Saudi REER

In previous studies, researchers have considered oil price to be a key driver of the REER in developing oil-exporting economies (Aleisa and Dibooĝlu 2002; Habib and Kalamova 2007; Hasanov 2010; Hasanov et al. 2017). Some even considered oil price as the only driver of the REER, ignoring other key fundamentals (IMF 2018, 2019; Suliman and Abid 2020). One of the novelties of our research is that instead of using oil price as the key explanatory variable of Saudi Arabia's REER, we model the impact of oil prices on REER indirectly. We do this primarily through government spending, NFA and productivity, as discussed below.

First, modeling the role of government spending is particularly integral for the objective of this study. Razek and McQuinn (2021) and Meshulam and Sanfey (2019) employed the ratio of government expenditure to GDP to model the impact of non-tradable goods and services on international competitiveness. Applying this ratio to Saudi economic data, Razek and McQuinn (2021) graphically illustrated that Saudi government expenditures are primarily directed to the non-tradable goods and services sector. Likewise, this is reflected in the PIF's strategy for 2021–2025 to achieve the Saudi Vision 2030 goals and support the development of the national economy. The strategy focuses on 13 sectors: renewables and utilities; aerospace and defense; automotive; transportation and logistics; food and agriculture; construction and building components and services; entertainment, leisure and sports; financial services; real estate; metals and mining; health care; consumer goods and retail; and telecom, media and technology (PIF 2021).

Second, a large portion of Saudi Arabia's government revenues come from oil exports (see, e.g., Al Moneef and Hasanov [2020]; Hasanov et al. [2021]). Government consumption, again regardless of how it is measured, has a considerable positive effect on the Saudi CPI, which is the numerator in the REER formula, as described in the data section.[4]

Third, unlike other fundamentals, such as productivity or government consumption, oil prices affect the REER indirectly, rather than directly. Considering the composition of the REER, oil prices do not directly affect domestic prices, prices charged by main trading partners or the nominal effective exchange rate (NEER). Likely channels whereby oil prices could affect domestic prices include oil export revenues,[5] government revenues and government expenditures.[6] In a number of studies (e.g., IMF [2018, 2019]), researchers have noted that the effect of oil prices on the NEER is quite limited in oil exporting economies with fixed exchange rate regimes. Oil is purchased in U.S. dollars (USD), and an increase (decrease) in oil prices results in an increase (decrease) in foreign reserves denominated in USD. This creates excess demand for the local currency in the foreign exchange market when the government converts its foreign reserves into the national currency for spending purposes. This could result in appreciation of the local currency, but it does not happen because the nominal exchange rate of the national currency to USD is fixed. This results in high prices as central banks in oil-dependent economies usually intervene in the foreign exchange market by selling or printing more national currency. The Saudi Arabian Monetary Authority (SAMA) alleviates pressure on the SAR–USD exchange rate by intervening in the forward market to ensure its long-term stability (Al-Hamidy 2012).

Fourth, because government spending is an intermediate element in transmitting the effect of oil prices to the REER, one could use either government spending or oil prices to empirically estimate an econometrically well-specified REER equation. In this regard, including oil prices but excluding all other theoretically predicted fundamentals of the REER is not econometrically viable. Empirically, linking the REER only to oil prices as in previous studies (e.g., IMF [2018, 2019]; Suliman and Abid [2020]) does not provide policymakers with a useful framework for adjusting REER movement. Put differently, oil prices are largely exogenous to domestic economic policies in oil-exporting economies, and they are not sufficiently under policymakers' control. Moreover, domestic economic policies in such economies have very limited to no effect on global oil price changes. Econometrically, such a bivariate framework can lead to serious issues such as omitted variable bias, because oil prices are not the only determinants of the REER. Besides, policymakers can directly influence government consumption as well as NFA, and consequently productivity, to reduce REER misalignment. Another novel aspect of our research is that we include government expenditure in the analysis, revealing the role of government spending in Saudi REER movements and helping policymakers address misalignments.

Similar to Clark and MacDonald (1999, 2004) and unlike Razek and McQuinn (2021), we use NFA instead of international reserves. In the modern world, currency exchange rates are driven not only by trade flows but also by international movements of capital. Theoretically, the impact of NFA on the REER is ambiguous, as countries try to attract more foreign investments and other assets to boost their economic growth. When inflows of assets exceed outflows, NFA are negative and create extra demand for the national currency, causing the REER to appreciate. Conversely, if outflows of foreign investments and other assets exceed inflows, the national currency may depreciate (see, e.g., Babetskii and Égert [2005]; Brixiova, Égert, and Essid [2014]; Égert, Lahrèche-Révil, and Lommatzsch [2004]).

In the aforementioned studies, researchers examined the impact of aggregate relative productivity. Razek and McQuinn (2021) accounted for productivity in the tradable versus non-tradable goods and services sectors. Another novel aspect of our research is that we examine the separate impacts of the relative productivities of the non-oil and oil sectors. Doing so yields useful information for policymakers about how the productivity differential between the non-oil sector and the rest of the world affects the REER differently than the productivity differential between the oil sector and the rest of the world. It also enables us to test the validity of the Balassa-Samuelson effect in the oil and non-oil sectors separately. It also allows us to examine the contribution of the non-oil sector to Saudi Arabia's competitiveness and to estimate the extent to which the non-oil sector can become an engine of long-term economic growth. The results may help the Saudi government make informed decisions on the appropriateness of either an export-led growth strategy or import substitution strategy. The literature states that an increase in productivity improves the competitiveness of a given country by raising the equilibrium level of the national currency. In other words, rather than reducing economic competitiveness, appreciation of the national currency caused by increased productivity actually improves competitiveness (see, e.g., Orszaghova, Savelin, and Schudel [2012]).

Lastly, we do not include factors such as the interest rate differential, openness or TOT for several reasons. First, publicly available data on the Saudi interest rate are not available for a long enough sample period (i.e., 30 years or more). For this reason, earlier studies on the exchange rate and currency demand did not consider it in their empirical analyses (see discussions in Al-Bassam [1990]; Al Rasasi and Banafea [2018]; Al Rasasi and Qualls [2019]; Chatah [1983]; Darrat [1984, 1986]; El Mallakh and Mallakh [1982]). This is true for measures of interest rates on both money and alternative assets. For example, SAMA Annual Statistics regarding interest rate measures on SAR deposits only date back to 1997. Additionally, it is unlikely that the interest rate differential between the Saudi economy and the rest of the world would play a significant role in capital movements. This is because financial markets are still in the development phase in Saudi Arabia, as in other Gulf Cooperation Council countries and developing economies (Al-Hamidy 2012; Al-Yousif 2000; Fasano and Wang 2001; Looney 1989). Moreover, the SAR exchange rate has been pegged to the USD since 1986; hence, Saudi interest rates simply mirror the dynamics of the U.S. federal interest rate. We also do not consider TOT or openness in our analysis, as both indicators are significantly shaped by the oil sector in oil-exporting developing economies (see Amano and Van Norden [1998]; Chen and Rogoff [2003]; Ferraro, Rogoff, and Rossi [2015]; Hasanov [2010]; Hasanov et al. [2017]; Suliman and Abid [2020]).[7] In a recent study, Razek and McQuinn (2021), included neither the interest rate differential nor TOT. They focused on estimating the long-term equilibrium exchange rate, which is the measure of external competitiveness, to calculate currency misalignments.

Thus, our REER relationship can be concluded as the following undefined function based on the above discussion of its determinants:[8]

$$REER_t = f(PRODDN_t, PRODDO_t, GC_t, NFA_t) \quad (2)$$

where $PRODDN_t$ is the non-oil sector productivity variable, $PRODDO_t$ is the oil sector productivity variable, GC_t is the government consumption variable and NFA_t is net foreign assets.

Babetskii and Égert (2005) discussed how productivity increases can lead to depreciation of the real exchange rate according to the class of new open economy macroeconomics (NOEM) models (see, e.g., Benigno and Thoenissen [2003]; MacDonald and Ricci [2002]). However, the literature mostly shows the opposite, as predicted by the Balassa-Samuelson concept. Similarly, many studies have found that government consumption is expected to cause the local currency to appreciate. This is mainly because most public spending is directed to the non-tradable sector, which leads to an increase in the prices of non-tradable goods, and thus an increase in overall price levels.

Égert, Lahrèche-Révil, and Lommatzsch (2004) highlighted that the literature is not conclusive about the effects of NFA on the real exchange rate (i.e., whether they are positive or negative). Such a consideration is not in line with traditional theories of the equilibrium exchange rate developed in the 1980s or earlier, which typically predict appreciation of the domestic currency due to increases in NFA. Therefore, we believe it deserves a detailed discussion. Traditional theories such as the portfolio balance approach have been strongly challenged by theoretical and empirical studies conducted since the 2000s. For example, Égert, Lahrèche-Révil, and Lommatzsch (2004), Alberola and Navia (2008) and Brixiova, Égert, and Essid (2014) theoretically showed that an increase in NFA does not necessarily lead to an appreciation of the national currency.

Égert, Lahrèche-Révil, and Lommatzsch (2004) proposed a theoretical framework in which NFA can have a negative or positive effect on the real exchange rate. The authors explained the ambiguity of the expected sign of NFA as follows. Economies, especially emerging and developing economies, rely on foreign savings to finance the catching-up process and economic development. During the catching up process (which typically takes a long time), they accumulate foreign liabilities that exceed their assets abroad, so the NFA position becomes negative. Consequently, rising foreign liabilities lead to an appreciation of the domestic currency. This appreciation might result from excess demand for the national currency in foreign exchange markets and a rising domestic price level caused by expanded aggregate demand and the Balassa-Samuelson effect. Once countries reach the target level of foreign liabilities in the very long run, they start paying interest, and any further increase in net foreign liabilities leads to depreciation of the real exchange rate. The authors empirically showed that an increase in NFA led to statistically significant depreciation of domestic currencies for a panel of 11 Central and Eastern European countries and a panel of eight emerging economies. However, their estimates show that increases in NFA led to the appreciation of domestic currencies in 15 OECD economies, which were advanced relative to the first two groups of countries. The results are robust to the econometric methods employed, specifications used and REER measures considered.

Alberola and Navia (2007, 2008) discussed a failure of traditional theoretical models of the real exchange rates, such as the portfolio balance approach. They developed a theoretical model in which the sign of the NFA coefficient in the real exchange rate equation is not necessarily positive. Instead, it depends on the difference between the real international interest rate (i.e., cost of financing foreign liabilities) and real economic growth rate of a given country. Obviously, for those countries where economic growth rates are higher than real international interest rates, the NFA coefficient is negative. That is, an increase (decrease) in NFA leads to depreciation (appreciation) of the real exchange rate of the domestic currency. The authors applied this framework to time series data and empirically showed that an increase in NFA led to appreciation of the Polish and Hungarian REERs but depreciation of the Czech REER.

Brixiova, Égert, and Essid (2014) developed a theoretical framework that predicts that the sign of NFA in the REER equation depends on the real interest rate in world markets and the coefficient in the NFA identity. In other words, NFA can have either appreciating or depreciating effects. The application of the developed theoretical model to time series data shows that an increase in NFA led to a depreciation of the Egyptian, Moroccan and Tunisian REERs. The results are robust through five different REER specifications and two econometric methods.

Aglietta, Baulant, and Coudert (1998), among others, discussed how economies aim for a certain steady-state level of NFA in the long run. This means that governments adopt policies to bring NFA close to target levels. In other words, if NFA levels are higher than the target, they can be reduced through appreciation of the REER. The appreciated REER makes exports from the domestic economy expensive for the rest of the world and imports cheap for the domestic economy. This causes the trade balance, and hence the current account balance, to run a deficit, and consequently, NFA levels decline. Increased aggregate demand due to expanded imports leads to a rise in domestic prices and thus to an appreciation of the real exchange rate. Thus, it appears that lower NFA levels are accompanied by appreciation of the REER. The opposite could be true if NFA levels are below target values.

A number of empirical studies based on the theoretical frameworks discussed above and others have also found mixed effects of NFA on the real exchange rate. For a panel of 28 European countries, Comunale (2018) estimated that an increase in NFA, as measured by the cumulative current account balance relative to GDP, causes depreciation of the REER. However, the impact is positive only when a panel of advanced European countries is considered. Lommatzsch and Tober (2004) found that an increase in NFA led to depreciation of the real exchange rate in the Czech Republic, regardless of the econometric method used. Burgess, Fabrizio, and Xiao (2003) estimated that a decrease in NFA (i.e., an increase in foreign liabilities) caused appreciation of the real exchange rate in Estonia, Latvia and Lithuania. Alonso-Gamo et al. (2002) also estimated that a decline in NFA over time caused appreciation of the Lithuanian REER. The main takeaway from these empirical studies is that an increase (decrease) in NFA can cause depreciation (appreciation) of the real exchange rate in developing, emerging and transitioning economies. However, it typically leads to appreciation (depreciation) of the real exchange rate in advanced economies.

Thus, equation (2) can be expressed as the following econometrically estimable specification:

$$reer_t = a_0 + a_1 proddn_t + a_2 proddo_t + a_3 gc_t + a_4 nfa_t + e_t \qquad (2a)$$

where a_i are the coefficients to be estimated, and e is the error term. We expect that $a_1 > 0$, $a_2 > 0$, and $a_3 > 0$. The sign of a_4 is theoretically ambiguous and will be determined empirically as discussed above. The variables denoted in lower-case letters in equation (2a) are the natural logarithmic transformations of the same variables in equation (2).

Once equation (2a) is econometrically estimated, then the equilibrium REER series (*REERE*) can be constructed as

$$REERE_t = exp(\widehat{a_0} + \widehat{a_1} PRODDN_t + \widehat{a_2} PRODDO_t + \widehat{a_3} GC_t + \widehat{a_4} NFA_t) \qquad (3)$$

where *exp* is the exponent operator, and the hats indicate estimated coefficients.

Consequently, a currency misalignment series is computed as the difference between the actual observed REER and the long-term equilibrium REER estimated using equation (3). The misalignment series provides very useful information about the price competitiveness position of a country in the international economy. If a given value of the series at a given point in time is positive (i.e., the actual REER is greater than the equilibrium REER), it means that the actual or prevailing REER has appreciated more than necessary. This can negatively impact the country's competitiveness. In this respect, not all appreciations are harmful to the export competitiveness of a given country: only those that result in the actual REER being above the equilibrium level (see, e.g., UNCTAD [2012]). Similarly, depreciation can help improve competitiveness when the actual REER is overvalued, that is, above its equilibrium value, as discussed by Javed, Ali, and Ahmed (2016) and others. Moreover, it is worth noting that productivity growth driven appreciation does not cause a loss of competitiveness, as highlighted by Orszaghova, Savelin, and Schudel (2012) and others.

Data

Our analysis covers annual time series data for the variables in equation (2) for the period 1980–2018.[9] See Razek and McQuinn (2021) for a detailed discussion of the economic justifications and appropriateness of studying this time period.

Real effective exchange rate (REER). The REER is a Consumer Price Index (CPI)-based multilateral exchange rate of the SAR against the currencies of Saudi Arabia's main trading partners. *REER* is calculated as below by the IMF's International Financial Statistics (World Bank, 2021):

$$REER = NEER \times \frac{CPI^D}{CPI^F}$$

where *NEER* is the nominal effective exchange rate index of the SAR. According to the World Bank (2021), it is the ratio (expressed on the base 2010=100) of an index of the SAR's period-average exchange rate to a weighted geometric average of exchange rates for the currencies of Saudi Arabia's main trading partners. Because the NEER index is based on 2010=100, the same is true for the REER index. CPI^D and CPI^F are CPI in Saudi Arabia and the weighted average CPI of the main trading partners of Saudi Arabia, respectively. The NEER is defined as the foreign currency price of the SAR. Hence, an increase in the NEER and REER means that the SAR has appreciated against the currencies of the Kingdom's main trading partners. The REER is an inflation-adjusted measure and a better indicator of competitiveness than the NEER because the former captures price differentials between a country and its trade partners. REER data are available from the World Development Indicators database (WDI; World Bank 2021). Chinn (2006) noted that a REER calculated using prices of tradable goods from sources such as the Producer Price Index and Wholesale Price Index may not be a good measure of competitiveness compared to the one calculated using CPI. This is because the former indexes may include a large component of imported intermediate goods, which is the case in Saudi Arabia. Moreover, the European Commission considers CPI-deflated REER as a measure of price competitiveness (European Commission 2002).

Productivity differential in the non-oil sector (*PRODDN*). One can use relative productivity in the tradable and non-tradable sectors to investigate their effect on the REER, its equilibrium and misalignment. In this study, however, we are mostly interested in how relative productivity in the non-oil and oil sectors have shaped the Saudi price competitiveness historically, and how they will continue to do so in coming years. This is because, while the oil sector has historically been the leading sector of the economy, Saudi Vision 2030—the country's strategic development roadmap—aims at expanding the non-oil sector. There are different ways of measuring relative productivity. One widely used method considers the ratio of GDP per capita in the home country to that in its main trading partners (or in the world, as a proxy). This measure is easy to calculate because GDP per capita data is readily available for many countries (e.g., see Chudik and Mongardini [2007]). Thus, the relative productivity in the non-oil sector is calculated as follows:

$$PRODDN = \frac{(GVANOIL/ER)/POP}{GDPPCW} * 100$$

where *GVAOIL* is gross value added by the non-oil sector of the Saudi economy, measured in millions of SAR at 2010 prices based on SAMA Yearly Statistics (SAMA 2018). This is defined as the GDP, excluding the mining and quarrying and oil refining sectors as well as net taxes. It is scaled to SAR by multiplying by 1 million to make it consistent with the measure of world GDP per capita. The resulting series is converted into USD terms by dividing the SAR–USD exchange rate (*ER*), that is, the SAR price to USD, collected from the WDI (World Bank 2021). The population of Saudi Arabia (*POP*) is taken from United Nations Statistics database. Finally, *GDPPCW* is the world's GDP per capita, measured in USD at 2010 prices, retrieved from the WDI (World Bank 2021).

Productivity differential in the oil sector (PRODDO). Similar to *PRODDN*, the variable is constructed as follows:

$$PRODDO = \frac{(GVAOIL/ER)/POP}{GDPPCW} * 100$$

where *GVAOIL* is the gross value added by the oil sector to the Saudi economy, measured in millions of SAR at 2010 prices and taken from SAMA (2018). This is defined as the GDP from the mining and quarrying and oil refining sectors. It is scaled to SAR by multiplying by 1 million to ensure consistency with the measure of *GDPPCW*. The resulting series is divided by *ER* to convert the values into USD.

As mentioned above, one of the novelties of this research is that it uses productivity differentials in the non-oil and oil sectors, that is, *PRODDN* and *PRODDO*, to capture Balassa-Samuelson effects of these sectors on the Saudi price competitiveness separately.

Ratio of government consumption to GDP (GC). This is the percentage ratio of the nominal Saudi Arabian government final consumption expenditure (*GC_Z*) to nominal Saudi GDP (*GDP_Z*), both collected from WDI (World Bank 2017).

$$GC = \frac{GC\_Z}{GDP\_Z} * 100$$

According to the World Bank definition, general government final consumption expenditure (formerly general government consumption) includes all current government expenditures associated with purchasing goods and services. This includes compensation of employees and most spending on national defense and security, but it excludes government military expenditures (World Bank 2021). For more detailed coverage of the sectoral components of government expenditure and the relationship between government and military expenditures, interested readers can refer to Razek and McQuinn (2021), as military expenditure is beyond the scope our paper.

Ratio of net foreign assets to GDP (NFA). This is the percentage ratio of Saudi Arabia's net foreign assets from WDI (World Bank 2021) to its GDP, both measured in SAR. The World Bank defines net foreign assets as the sum of foreign assets held by monetary authorities and deposits held in banks, less foreign liabilities (World Bank 2021).

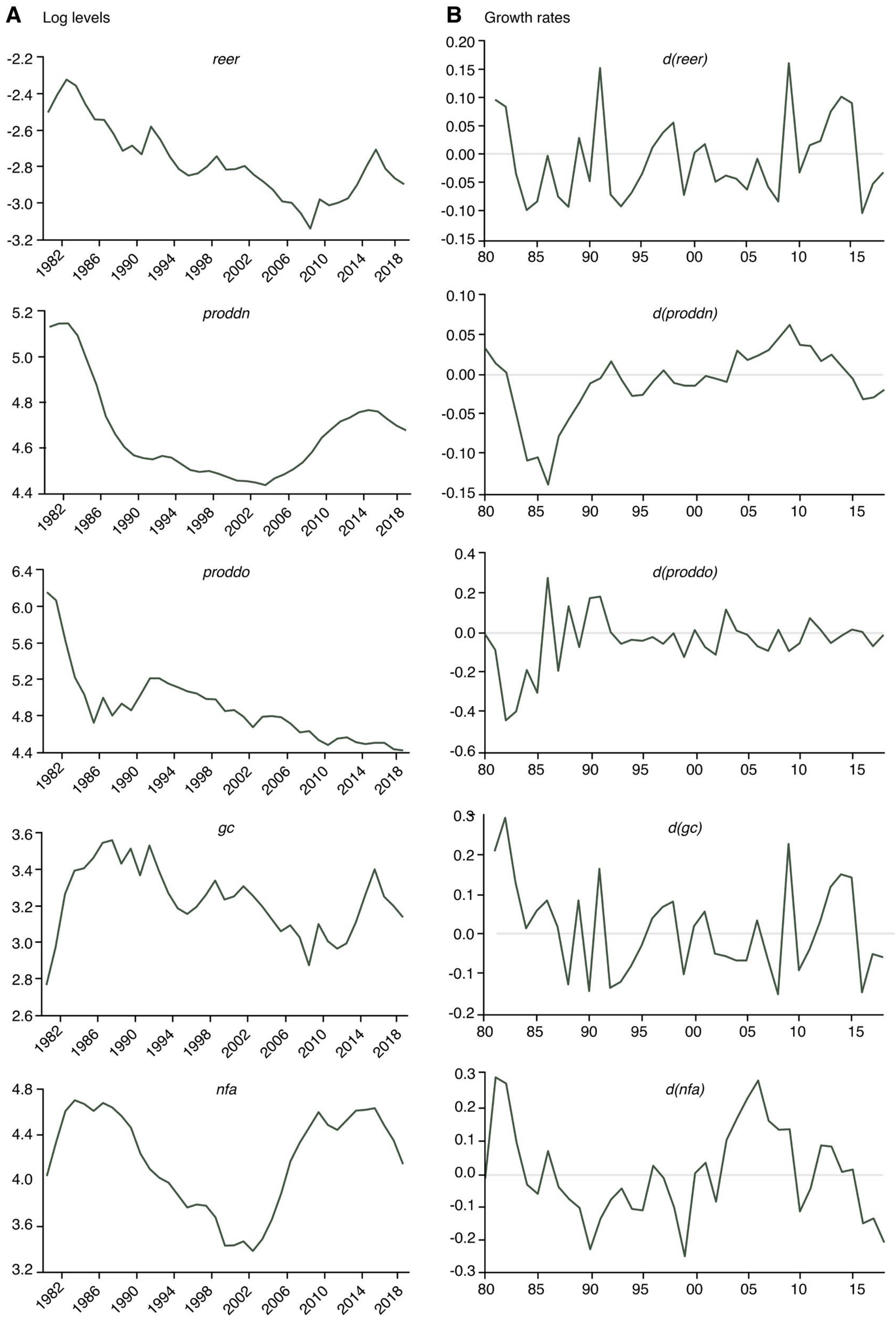
For illustrative purposes, Figure 1 depicts the natural logarithmic (log) levels (indicated by lowercase labels) and first differences of the variables used in the empirical analysis.

Econometric Methodology

We applied the cointegration test to annual time series data for the period 1980–2018 and then estimated the coefficients of the long-run relationship between *reer* and its determinants. Prior to doing so, we tested for stochastic properties of the variables by performing standard unit root tests and those designed for structural breaks.

We employed autoregressive distributed lags (ADL) as our primary long-run estimation method, as it has several advantages that make it more suitable for our case than other methods. ADL long-run estimations and the ADL bounds test for cointegration profoundly outperform all their counterparts, including vector autoregressive (VAR) methods in small samples. When the ADL technique is used, simultaneous estimations of the long- and short-run coefficients can be generated quite easily via ordinary least squares (OLS) regression. This can be applied regardless of whether the integration order of regressors is one, zero or a mixture of both (Enders 2015; Pesaran and Shin 1995; Pesaran, Shin, and Smith 2001). Nonetheless, there is still a need to test the unit root properties of variables. This is because it would be useless to search for long-run relationships if the dependent variable is an I(0). Moreover, the ADL-based estimation and testing can yield misleading results if an I(2) variable is involved in the analysis.

Figure 1. Log levels and growth rates of the variables.



Source: Authors' construction.

Hence, we employed two conventional unit root tests, that is, the Augmented Dickey-Fuller (ADF; Dickey and Fuller 1979) and Phillips-Perron (PP; Philips and Perron 1988), to ensure robustness. Enders and Lee (2012b) explained that standard Dickey-Fuller-type unit root tests such as ADF and PP do not have the initial value problem and are straightforward to use. Thus, they outperform generalized least squares de-trended types of unit root tests. As a further robustness check, we also used unit root tests with structural breaks, such as the ADF test with structural breaks (ADFBP) developed by Perron (1990), Perron and Vogelsang (1992a, 1992b), and Vogelsang and Perron (1998). We also used the ADF test with the Fourier approximation, which was developed by Enders and Lee (2012a, 2012b) to address multiple breaks resulting in a non-linear trend in data. Enders and Lee (2012a, 2012b) showed that this test has a number of advantages over other unit root tests deigned for structural breaks.

We applied the maximum likelihood-based Johansen cointegration test (JOH) first in the empirical analysis, although our primary estimation and testing method was ADL. We employed this strategy because the JOH, as a system-based cointegration test, is the only method that can reveal whether multiple cointegration relationships exist, whereas the ADL bounds test or other single-equation-based and residual-based cointegration tests cannot. In other words, the theory of cointegration articulates that *n* variables can establish a maximum of *n-1* cointegrated relationships, and a system-based test, such as JOH is the only method to discover this. The key point here is that if there is more than one cointegrating relation, but they are ignored, it will cause information loss. It may even cause an omitted variable bias issue if the long-run residuals of the other cointegrating relation enters the equilibrium correction model of the interested variable in a statistically significant way (see, e.g., Badinger [2004]; Dibooglu and Enders [1995]; Enders [2015]). The ADL and other single-equation-based methods (referred to below), can be used to estimate long-run coefficients if the JOH indicates only one cointegrating relationship among the variables under consideration. In the reduced rank approach of the JOH method, a VAR model is first specified and estimated. Then it is transformed into a VEC model to test for cointegration. See Enders (2015); Johansen (1988, 1992), Johansen and Juselius (1990), and Juselius (2006) for descriptions of the JOH.

One of the key issues we needed to consider in the empirical analysis was the small sample bias correction in testing cointegration. To address this, we applied corrections to both the JOH and ADL bounds testing methods to verify that our inferences about the cointegration properties of the variables were robust. Cheung and Lai (1993), Reimers (1992), and Reinsel and Ahn (1992) explained that the trace and maximum eigenvalues (i.e., the cointegration test statistics of the JOH) may be biased towards suggesting more than one cointegrating relationship, particularly when the sample size is small and the number of variables included in the cointegration analysis is large. Therefore, we applied the correction method developed by Reimers (1992) and Reinsel and Ahn (1992) to the JOH. As an additional robustness check, we employed Narayan's (2005) critical values in the ADL bounds test for cointegration, as these critical values were tabulated for small samples compared to those suggested by Pesaran, Shin, and Smith (2001). Lastly, we applied the degrees of freedom correction to the estimations of the long-run coefficients in the ADL, we and employed additional long-run estimation methods described below.

To check the robustness of the estimated long-run coefficients, and thereby propose well-grounded policy recommendations, we used fully modified ordinary least squares (FMOLS), canonical cointegrating regression (CCR) and dynamic ordinary least squares (DOLS) methods alongside the ADL method. Thus, we used dynamic estimators such as ADL and DOLS and static estimators such as FMOLS and CCR.

Results of the Empirical Analysis and Robustness Checks

Unit Root Test Results

Table 1 reports the ADF and PP unit root test results. The graphical illustrations of the variables in Figure 1 suggest that only *proddo* may include a linear deterministic trend in its data generation process (DGP). Hence, it is included in the ADF and KPSS tests of this variable. Enders and Lee (2012b) argued that if a linear trend is not necessary, it should be excluded because a test equation without a linear trend is more powerful.

For the variables in level, the ADF test results indicate that all variables except *proddo* are unit root processes at the 5% significance level. For the *proddo*, although the ADF test result suggests trend stationarity, the PP test result suggests a unit root process. The graphical illustration of *proddo* does not favor either the ADF or the PP result, as it does not provide clear information about whether the variable follows a trend-stationary or difference-stationary process. Because the variable has a trend that continues until 1985 and then another trend prevails from 1992 onward, a unit root test with a structural break is preferable. To this end, we ran the ADF test with a structural break for *proddo*. We set the maximum lag order to two and used the Schwarz criterion to select the optimal lag length. We selected 1992 as the break date, and we considered this break to be innovative because it evolved gradually from 1985 to 1992. The test sample value of -3.12 is smaller than the critical values of -4.52, -3.89 and -3.61 at the 1%, 5% and 10% significance levels, respectively, in absolute terms. This result indicates that *proddo* is a unit root process with a broken trend. We also applied the

Table 1. Unit root test results.

Variable	Augmented Dickey-Fuller					Phillips-Perron			
	Test value	*t*	*c*	Neither	*k*	Test value	*T*	*c*	Neither
reer	-2.545030		x		1	-2.282108		x	
proddn	-2.621165*		x		1	-2.049572		x	
proddo	-3.923043**	x			2	-2.907963	X		
gc	-2.844594*		x		0	-3.015886**		x	
nfa	-2.182802		x		1	-1.617933		x	
d(*reer*)	-3.305123***			x	0	-3.307186***			x
d(*proddn*)	-1.781354*			x	0	-1.920298*			x
d(*proddo*)	-5.089681***		x		0	-5.170854***		x	
d(*gc*)	-5.583065***			x	0	-5.583198***			x
d(*nfa*)	-3.159805***			x	0	-3.349197***			x

Source: Author's estimations.
Notes: The maximum lag order is set to two, and the optimal lag order (*k*) is selected based on the Schwarz criterion in the tests; ***, ** and * indicate rejection of the null hypotheses at the 1%, 5% and 10% significance levels, respectively. Critical values for the tests are taken from MacKinnon (1996). The final unit root test equation can include one of three possibilities: intercept and trend (*t*), intercept only (*c*) and neither of them (*neither*); x indicates that the corresponding option was selected in the final unit root test equation.

ADF test with a structural break to the first difference of *proddo* with the same set up as above, but this time considering the break in the intercept. The test sample value of -4.89 is greater than any critical values in absolute terms, suggesting stationarity in the growth rate of *proddo* with an intercept break.

The PP test results suggest the unit root process applies to all variables except for *gc*, which seems to be level stationary at the 5% significance level.[10] However, the graphical illustration of *gc* in Figure 1 clearly shows a pattern of non-stationarity. Moreover, the estimated coefficients on the lagged level of the dependent variables, that is, gc_{t-1} in the ADF and PP tests, are -0.26. This means that the autoregressive coefficients are 0.74, which is more in favor of a unit root process than a stationary process. Thus, *gc* can be considered a unit root process.

For the first difference of the variables, which are the growth rates, the results of both the ADF and PP tests suggest stationarity at the 1% significance level. That conclusion for *d*(*proddn*) holds only at the 10% significance level. One can suspect that this weak significance is caused by obvious breaks in the growth rate, as illustrated in Figure 1. Hence, one may wish to apply a unit root test with structural break. To this end, one should not apply the ADF test with one structural break, as Figure 1 illustrates at least three broken trends. Therefore, we ran Enders and Lee's (2012a, 2012b) ADF test with the Fourier approximation. This test outperforms other unit root tests with multiple structural breaks (Enders and Lee 2012a, 2012b). The test results, which are available from the authors on request, indicate that *d*(*proddn*) is a stationary variable with breaks.

Overall, we conclude that all the variables are unit root processes at their log levels, and their growth rates are stationary. In other words, they all follow I(1) processes.

Cointegration Test and Long-run Estimation Results

As discussed in the methodology section, we first tested the number of cointegrated relations using the JOH. To this end, we followed the methodological guidelines provided by Juselius (2006) and others by first estimating a VAR of *reer, proddn, proddo, gc* and *nfa*. We noticed that decreasing the lag order from two to one caused a serial correlation issue, which is a serious problem for the JOH method. Hence, we selected the two-lag order as the optimal length. The VAR with two lags successfully passed all post-estimation tests, and therefore was valid for transforming a VEC model to test for cointegration. Table 2 presents the test results.

Panels A through C indicate that the residuals of the estimated VAR do not have any issues with serial correlation, non-normality or heteroscedasticity at the 5% significance level. Additionally, Panel D shows that the VAR is stable, as none of the characteristic roots are outside the unit circle. In general, the estimated VAR model fits the data well. As show in Panel E, both the trace and maximum eigenvalue test statistics suggest only one cointegration relationship between the variables after the small sample bias adjustment, regardless of the test type considered. The key message conveyed by Table 2 is that the variables (i.e., *reer, proddn, proddo, gc* and *nfa*) form only one cointegrated relationship. Therefore, we can use the ADL as well as DOLS, FMOLS and CCR to estimate the long-run coefficients of this single cointegration relationship among the variables.

We applied the ADL bounds test developed by Pesaran, Shin, and Smith (2001) to equation (2a) to see whether the results support that of the JOH. We selected a maximum lag order of two, as we did in the VAR analysis above, and we used the Akaike

Table 2. VAR and VEC post-estimation and cointegration test results.

Panel A: Serial correlation LM test [a]

Lags	LM-statistic	p-value
1	29.74	0.23
2	26.71	0.37
3	17.75	0.85

Panel B: Normality test [b]

Statistic	χ^2	d.f.	p-value
Skewness	1.51	5	0.91
Kurtosis	1.84	5	0.87
JB	3.35	10	0.97

Panel C: Heteroscedasticity test [c]

White	χ^2	d.f.	p-value
Statistic	333.20	300	0.09*

Panel D: Stability test [d]

Modulus	Root
0.93	0.93
0.91	0.84 – 0.35i
0.91	0.84 + 0.35i
0.88	0.86 – 0.19i
0.88	0.86 + 0.19i

Panel E: Johansen cointegration test summary

Trend in data:	None	None	Linear	Linear	Quadratic
Test type:	(a) No C or t	(b) C	(c) C	(d) C and t	(e) C and t
Trace ^{adj}:	1	1	1	1	1
Max-eigenvalue ^{adj}:	1	1	1	1	1

Source: Author's estimations.
Notes: [a] The null hypothesis in the serial correlation LM test is that there is no serial correlation at lag order h of the residuals. [b] System normality tests with the null hypothesis of the residuals are multivariate normal. [c] The White heteroscedasticity test uses the null hypothesis of no cross terms heteroscedasticity in the residuals. [d] The VAR stability test results show that no roots of polynomial characteristics are outside the unit circle. *adj* is the small sample bias adjustment, which was made for the trace and maximum eigenvalue test statistics using the method developed by Reinsel and Anh (1992) and Reimers (1992); χ^2: chi-squared; LM: Lagrange multiplier; JB: Jarque-Bera; *d.f.:degree of freedom; p-value: probability value; c*: intercept; *t*: trend. * denotes the rejection of the null hypothesis at the 10% significance level. Estimation period: 1980–2018.

information criterion to select the optimal lag lengths for each variable.[11] One of the merits of the ADL is that different lag lengths can be selected for different variables, unlike in the VAR/VEC framework. EViews 11.0 selected the ADL (2, 0, 2, 2, 0) specification after evaluating 162 rival specifications. The results of the cointegration and post-estimation tests as well as the estimated long-run coefficients for equation (2a) are documented in Table 3.

The ADL (2, 0, 2, 2, 0) specification successfully passes the serial correlation, heteroscedasticity, ARCH and normality tests, as reported in Table 3. Additionally, the specification does not have any

Table 3. ADL estimation and test results.

proddn	*proddo*	*gc*	*nfa*	*c*
Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)
0.71 (0.00)	0.18 (0.00)	0.67 (0.00)	-0.12 (0.06)	-1.02 (0.16)

Source: Author's estimations.
Note: $\chi^2_{SC} = 3.30(0.06)$; $\chi^2_{ARCH} = 2.31(0.12)$; $\chi^2_{HETR} = 0.55(0.81)$; $JB_N = 1.04(0.60)$; $F_{FF} = 0.79(0.38)$; $F_W = 8.97$.
Pesaran, Shin, and Smith's (2001) upper-bound critical values in the case of $k = 4$ and $T = 100$ are 4.37, 3.49 and 3.09 at the 1%, 5% and 10% significance levels, respectively. Narayan's (2005) upper-bound critical values in the case of $k = 4$ and $T = 35$ are 5.53, 4.09 and 3.46 at the 1%, 5% and 10% significance levels, respectively. The dependent variable is *reer*; *c* denotes the intercept term. F_{SC}, F_{ARCH}, F_{HETR}, F_{FF} and F_W denote *F* statistics to test the null hypotheses of no serial correlation, no autoregressive conditioned heteroscedasticity, no heteroscedasticity in the residuals, no functional form misspecification and no cointegration in the Wald test, respectively; JB_N indicates the Jarque-Bera statistic to test the null hypotheses of normal distribution of the residuals. *k* and *T* are the number of regressors and number of observations, respectively.

Table 4. Long-run elasticities from DOLS, FMOLS and CCR.

Method	*proddn*	*proddo*	*gc*	*nfa*	*c*
	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)
DOLS	0.89 (0.00)	0.20 (0.00)	0.51 (0.00)	-0.18 (0.02)	-1.27 (0.22)
FMOLS	1.24 (0.00)	0.22 (0.01)	0.68 (0.00)	-0.25 (0.00)	-3.16 (0.00)
CCR	1.23 (0.00)	0.24 (0.00)	0.65 (0.00)	-0.24 (0.00)	-3.15 (0.00)

Source: Author's estimations.
Note: The dependent variable is *reer*; *c* is the intercept term.

issue with functional form misspecification. The test of the null hypothesis of no cointegration yields a sample *F*-value of 8.97. This value is higher than Pesaran, Shin, and Smith's (2001) upper-bound critical value in the case of $k = 4$ and $T = 100$ at the 1% significance level, which is 4.37. The sample *F*-value also far exceeds Narayan's (2005) upper-bound critical value for the sample size of 35 at the 1% significance level, which is 5.53. Hence, we conclude that there is a cointegrated relationship among *reer, proddn, proddo, gc* and *nfa* after considering small sample critical values. The results for the ADL bounds test for cointegration support those of the JOH test in Table 2. Because the variables are cointegrated, the estimated coefficients are not spurious and can be interpreted as long-run coefficients. The estimated long-run coefficients from the DOLS, FMOLS and CCR for equation (2a) are presented in Table 4.

Additional Robustness Checks

We also checked whether our selected specification, that is, equation (2a), is robust to the consideration of other variables. One can consider international trade measures, such as trade openness (*OP*) or *TOT*, in modeling the behavior of the REER in standard economies. However, as we discussed in section 3, several studies have shown that these measures are not relevant when modeling the REER of net oil-exporting economies. Because the international trade of these economies is heavily driven by the oil sector (oil exports and/or price), accounting for the effect of the oil sector indirectly (e.g., through government consumption, as we did in this study) or directly (e.g., by including oil prices or revenues) makes these trade measures irrelevant in the REER analysis. We empirically tested this concept by including *OP* and *TOT* in equation (2a) one at a time (see Appendix A for details about the variables).[12] The aim was to check whether these variables can add theoretically consistent and statistically significant information to our long-run estimations reported in tables 3 and 4 to help explain movements in the REER. For further robustness, we estimated the effects of *OP* and *TOT* using all four methods. Table 5 documents the estimation results.

As shown in Table 5, neither *op* nor *tot* provides useful information, as their estimated long-run coefficients are statistically insignificant across all the methods. The long-run coefficient of *tot* is statistically significant at the 5% level in the ADL estimation in the table. However, this specification, that is, ADL (1, 2, 1, 0, 0, 2), has two serious issues: serial correlation in the residuals and functional form misspecification. These are crucial problems that invalidate the estimation results, including the estimated coefficients. We tried to find an ADL specification for *tot* that is free of serial correlation and misspecification. However, regardless of whether one- or two-lags is considered as the maximum lag order and which

Table 5. Extended long-run estimations using *OP* and *TOT.*

Method	*proddn*	*proddo*	*gc*	*nfa*	*op*	*tot*	*c*
	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)	Coef. (*p*-value)
ADL	0.70 (0.00)	0.15 (0.04)	0.73 (0.00)	-0.12 (0.06)	0.14 (0.59)	---	-1.77 (0.18)
	1.20 (0.00)	-0.29 (0.19)	0.66 (0.00)	0.00 (0.99)	----	-0.44 (0.03)	0.23 (0.81)
DOLS	0.91 (0.00)	0.19 (0.01)	0.62 (0.00)	-0.20 (0.01)	0.41 (0.15)	---	-3.25 (0.06)
	0.69 (0.04)	0.28 (0.03)	0.54 (0.00)	-0.15 (0.04)	----	0.07 (0.56)	-1.17 (0.22)
FMOLS	1.14 (0.00)	0.19 (0.05)	0.79 (0.00)	-0.24 (0.00)	0.26 (0.39)	---	-5.51 (0.20)
	1.28 (0.00)	0.20 (0.03)	0.58 (0.00)	-0.21 (0.00)	----	-0.05 (0.53)	-1.20 (0.67)
CCR	1.12 (0.00)	0.22 (0.01)	0.74 (0.00)	-0.23 (0.00)	0.24 (0.46)	---	-4.91 (0.23)
	1.24 (0.00)	0.23 (0.02)	0.58 (0.00)	-0.21 (0.00)	----	-0.03 (0.73)	-1.29 (0.67)

Source: Author's estimations.
Note: The dependent variable is *reer*; *c* is the intercept term. *op* and *tot* are the natural logarithm expressions of *OP* and *TOT*. In the ADL estimation for *op*, the maximum lag order of two is considered, and the final specification of ADL (2, 0, 2, 2, 0, 0) is selected by the Akaike information criterion as the Schwarz-based selection has a serial correlation issue. The post-estimation tests results are:

$$\chi^2_{SC} = 2.32(0.12);\ \chi^2_{ARCH} = 1.86(0.17);\chi^2_{HETR} = 0.98(0.49);\ JB_N = 2.14(0.34);\ F_{FF} = 2.61(0.12);\ F_W = 7.52.$$

In the ADL estimation for *tot*, the maximum lag order is set to two, and regardless of the information criterion considered, the final selected specification is ADL (1, 2, 1, 0, 0, 2). The post-estimation tests results are:

$$\chi^2_{SC} = 3.87(0.04)^{**};\ \chi^2_{ARCH} = 0.32(0.58);\chi^2_{HETR} = 1.60(0.16);\ JB_N = 1.72(0.42);\ F_{FF} = 3.49(0.07)^{*};\ F_W = 8.97$$

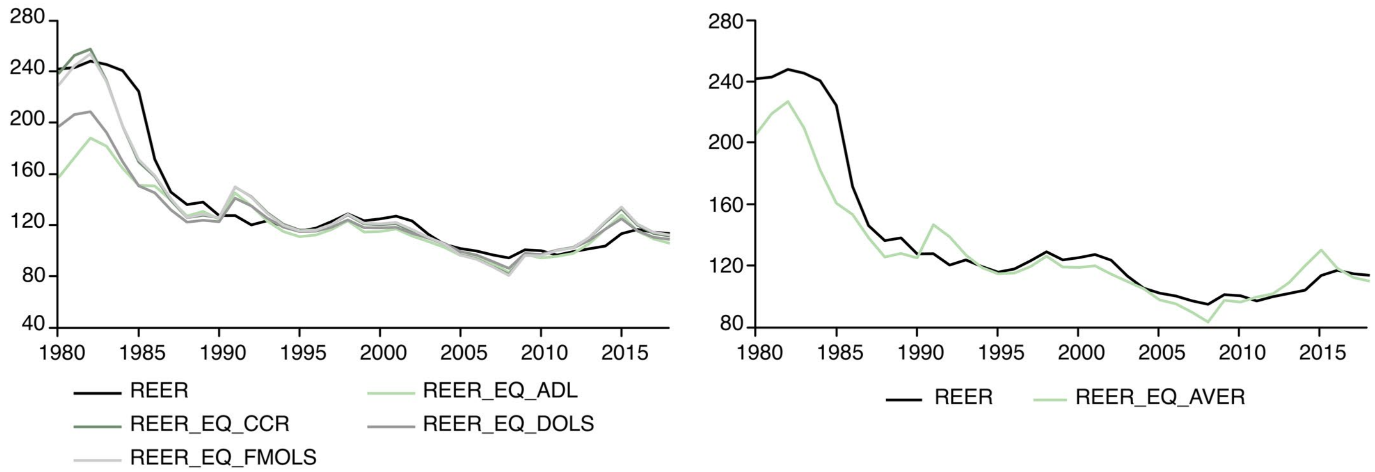
information criterion is preferred, these issues persist. These results support the contention that international trade measures, such as *OP* and *TOT*, which are considered in modeling the REER in standard economies, do not provide explanatory information if the impact of the oil sector is already directly or indirectly accounted for in the analysis. As expected, the variables became statistically significant if the productivity differentials in the oil sector are excluded from the estimations. The results of these estimations are not reported here to conserve space but are available from the authors on request. Thus, we conclude that the estimated long-run coefficients reported in tables 3 and 4 are robust and can be used in additional analyses.

Equilibrium REER and Currency Misalignment

Because we concluded that the estimated long-run coefficients for equation (2a) presented in tables 3 and 4 are robust, we used them to construct the equilibrium and misalignment series of the REER using equation (3). The graph on the left side of Figure 2 illustrates the equilibrium REER series constructed using the estimated coefficients from the ADL, DOLS, CCR and FMOLS models alongside the actual REER, thereby demonstrating how different methods yield similar results. The right-hand graph takes the average of the equilibrium values, estimated from the four methods on the left graph, and compares the resulting equilibrium values with the actual REER values. This makes it easy for readers to observe how these two REER series are similar or different over time.

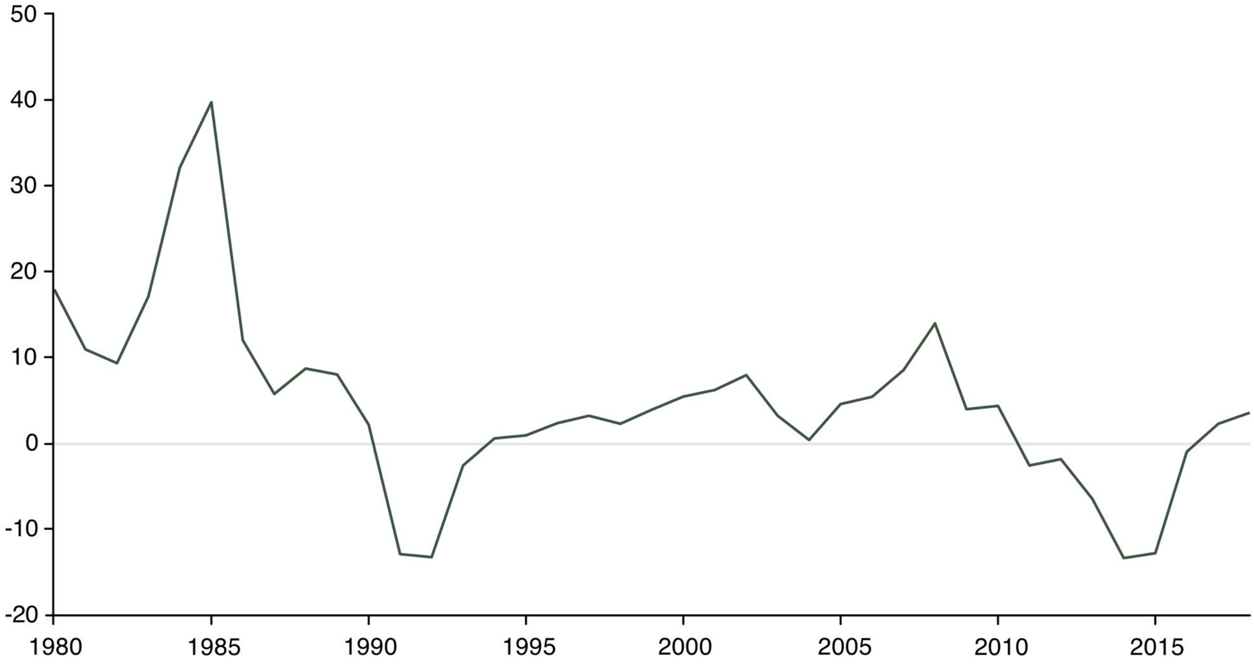
Finally, Figure 3 plots the calculated misalignment values over time. We discuss figures 2 and 3 in the next section.

Figure 2. Actual and equilibrium REER series, 1980–2018.



Source: World Bank (2021) data and authors' estimations.

Figure 3. REER misalignment, %.



Source: Authors' construction.

Discussion

We conclude that the natural logarithmic expressions of the variables are non-stationary with and without structural breaks, depending on the variable considered. In addition, their first differences are stationary based on the unit root test results in Table 1. Put differently, *reer, proddn, proddo, gc* and *nfa* follow an I(1) process. The non-stationarity assumes that shocks to the variables can create permanent effects. Thus, their means, variances and covariances change over time. In contrast, the stationary forms of our variables, that is, *d*(*reer*), *d*(*proddn*), *d*(*proddo*), *d*(*gc*) and *d*(*nfa*), assume that shocks to the stationary sequence of the variables are temporary. Hence, their means, variances and covariances do not change over time.[13]

Because we concluded that our variables follow an I(1) process, it is possible that these variables establish a long-run cointegration relationship. The results of two different tests—the JOH, a system-based test, and the ADL bounds test, a single-equation-based one—indicate a single long-run relationship among *reer, proddn, proddo, gc* and *nfa* (see tables 2 and 3). The interpretation of this cointegration is that the REER moves together with productivity differentials in the non-oil and oil sectors as well as with government consumption and NFA in the long-run and establishes a relationship, which is consistent with economic theory. The key message of cointegration here is that, if we estimate the parameters of the relationship established between the non-stationary sequences of the REER, productivity differentials in the non-oil and oil sectors, government consumption and NFA, we find they are not spurious and can be used for research or policy purposes to investigate the movement of the REER. We estimated the parameters of this long-run relationship and reported them in tables 3 and 4. Before proceeding to the economic interpretations, it is worth noting that the coefficients estimated using different methods are quite close to each other, considering our small sample size. This gives us confidence that our results are robust, and our policy recommendations are well-grounded. We use average values of the coefficients estimated from four different methods in the discussions below.[14]

On average, a **1.0%** rise in the non-oil sector productivity differential leads to a **1.0%** appreciation of the REER. The same rise in the productivity differential in the oil sector causes a **0.2%** appreciation in the long run. Sign-wise, the findings are consistent with the theory of the equilibrium exchange rate. According to the Balassa-Samuelsson concept, increased productivity in the tradables sector leads to price increases in the non-tradables sector, and the exchange rate appreciates as a result. This hypothesis holds true for both the non-oil and oil sectors in Saudi Arabia, as we found statistically significant coefficients. It appears that the appreciation effects of the productivity differential between the non-oil sector and the rest of the world is remarkably higher than that of the oil sector. As discussed in the exchange rate literature, appreciation resulting from increased productivity does not harm competitiveness, and even strengthens it (see, e.g., Orszaghova, Savelin, and Schudel 2012). Because increased productivity makes exports more competitive and imports cheaper, it is a key target that every country tries to achieve. Thus, an increase in productivity in the non-oil and oil sectors relative to the productivity of the rest of the world makes the Saudi economy more competitive.

A **1%** expansion in government final consumption is associated with a **0.6%** appreciation of the REER. An increase in government final consumption increases domestic aggregate demand (particularly demand for non-tradable goods) and prices rise, causing the REER to appreciate (e.g., see Meshulam and Sanfey [2019]). In Saudi Arabia, it should be mentioned that government spending, including consumption, significantly shapes the macroeconomic outlook (e.g., see Hasanov et al. [2021]). Hence, it has strong implications for the real exchange rate and competitiveness, just like other net oil-exporting developing economies. It is worth reporting that, on average, government expenditure (government final consumption) was 38% (26%) of GDP at current prices during 1980–2018, with an upward trend after 2008. Additionally, on average, 50% of the government final consumption was attributed to wages, salaries and other allowances for government employees during the same period. If we add the government's purchases of domestically produced goods and services to increase local content, as highlighted in Saudi Vision 2030, it can be concluded that a major portion of government final consumption is realized in the domestic economy. This increases aggregate domestic demand and, in turn, prices rise, leading to appreciation of the riyal. The appreciated REER might make the Kingdom's exports, particularly non-oil exports less competitive, and imports become less expensive, which would not be favorable for domestic production. Both outcomes (i.e., expensive exports and cheap imports) might create challenges for diversification, which is very important for the Kingdom to achieve, as highlighted in the Saudi Vision 2030 master plan.

Lastly, the REER depreciates by **0.2%** when NFA increases by **1%** in the long run. Theoretically, the impact of NFA on the REER is ambiguous, as we discussed in Section 3. In this regard, our finding of a negative impact is expected. As concluded in Section 3, empirical studies have usually found a negative impact of NFA on the real exchange rate in developing and emerging economies, and a positive impact in advanced economies. Our finding aligns with previous findings because Saudi Arabia is considered a developing/emerging economy. Recall that we used the World Bank's definition of NFA, that is, the sum of foreign assets (any portfolio investments, including foreign currencies) held by Saudi monetary authorities and bank deposits minus their foreign liabilities. In other words, it is the difference between a given country's clams on foreigners and its liabilities to them (Krugman, Obstfeld, and Melitz 2015, 51). The data on Saudi Arabia's NFA position show that it was consistently positive throughout the analysis period. This indicates that outflows from Saudi Arabia into foreign investments and other assets were greater than inflows of foreign assets into Saudi Arabia (see Figure 1). Theoretically, if outflows are greater than inflows, demand for foreign currency increases, leading to depreciation of the national currency (the riyal in our case). According to the accounting definition of balance of payment, the value of NFA is the cumulative sum of the current account balance, which in turn is the sum of net exports, net income and net current transfers. Net exports, which constitute the main source of the Kingdom's NFA, were consistently positive during 1980–2018, driven mainly by oil exports, except from 1983 to 1989 and in 2015. This enabled the Kingdom to invest significantly abroad. A negative association between NFA and the REER would be also related to the fixed-exchange rate framework. To be precise, when the riyal starts to appreciate as a result of internal and external factors, SAMA injects more USD into the foreign exchange market to maintain a fixed USD–riyal nominal bilateral exchange rate. This injection reduced the Kingdom's foreign assets/reserves.

Alberola and Navia's (2007, 2008) studies were influential and have served as the theoretical underpinning of many other studies in which researchers examined the REER in different countries. As we discussed in section 3, the authors built a theoretical framework in which the sign of the NFA coefficient in the real exchange rate equation is determined by the difference between the real international interest rate (*r*) and real economic growth rate of a domestic economy (*g*). Put differently, if *g* is greater than *r*, the sign becomes negative, and vice versa. This analytical framework allows for a descriptive test (i.e., one can subtract *g* from *r* to examine whether the difference is predominantly positive or negative over a given period to get an idea of the sign of NFA). We did this as a robustness test for our finding of a negative effect of NFA on the REER. Figure 4 illustrates the results. The figure shows that the difference is mostly negative (i.e., in 27 out of 39 observations) between 1980 and 2018. Five of the 12 positive differences occurred between 1980 and 1987, which was an unusual period characterized by a prolonged recession in the Saudi economy (see, e.g., Al Moneef and Hasanov [2020]; Hemrit and Benlagha [2018]). Moreover, the positive differences in 1999, 2001–2002 and 2009 may have been associated with negative Saudi GDP growth rates caused by the Russian ruble crisis, Asian financial crisis and global financial crisis, respectively. This leaves only three "normal" years in which *r* was larger than *g*. To this end, Figure 4 supports our estimation of the negative impact of NFA on the REER (see tables 3 and 4). As a further robustness check, we calculated the cumulative sum of the Saudi current account and adjusted it with GDP values, both in current USD using WDI (World Bank 2021) data. We included the resulting series in the REER estimates as another measure of NFA, in line with the literature (see, e.g., Alberola and

Figure 4. Difference between the real international interest rate (*r*) and Saudi real GDP growth rates (*g*).[15]

Source: Authors' construction.

Navia [2008]). This measure of NFA is negative and statistically significant in the DOLS, FMOLS and CCR estimates, but it is negative and insignificant in the ADL estimate (results are available from the authors upon request). This finding further supports the negative effects of NFA on the REER reported in tables 3 and 4.

Regarding how the aforementioned driving forces shaped the Saudi REER from 1980 to 2018, some observations from figures 2 and 3 are worth discussing. First, if we ignore abnormal times, such as the economic recession from 1980 to 1987, the Gulf War from 1991 to 1992, the oil market boom in 2008 and the oil price drop from 2014 to 2016, REER misalignment values stay between 8.7% and -6.5% over the entire period, which is an acceptable range for deviations of the actual REER from its equilibrium values (see Figure 3). Put differently, the right-hand graph in Figure 2 illustrates that actual values (blue line) were quite close to equilibrium values (orange line) if we ignore abnormal observations. As noted in an IMF (2011) report, when government spending exceeds the equilibrium level, modest currency misalignments occur. This implies that SAMA's exchange rate policy was quite successful in that the actual REER remained close to the equilibrium level. This is desirable because when the REER exceeds the equilibrium, Saudi exports (particularly non-oil exports) become expensive for the rest of the world, and when the REER is lower than the equilibrium, imports become costly for the Kingdom.

Second, the misalignment values in Figure 3 are mainly positive, and actual REER values exhibit an upward trend, particularly since 1993. This is a reasonable finding because high oil prices (and thus, huge oil revenues) placed appreciation pressure on the riyal for a long time. However, the fixed exchange rate regime curbed this appreciation significantly. In this regard, in line with Razek and McQuinn (2021), it can be concluded that the fixed exchange rate regime benefited the Kingdom.

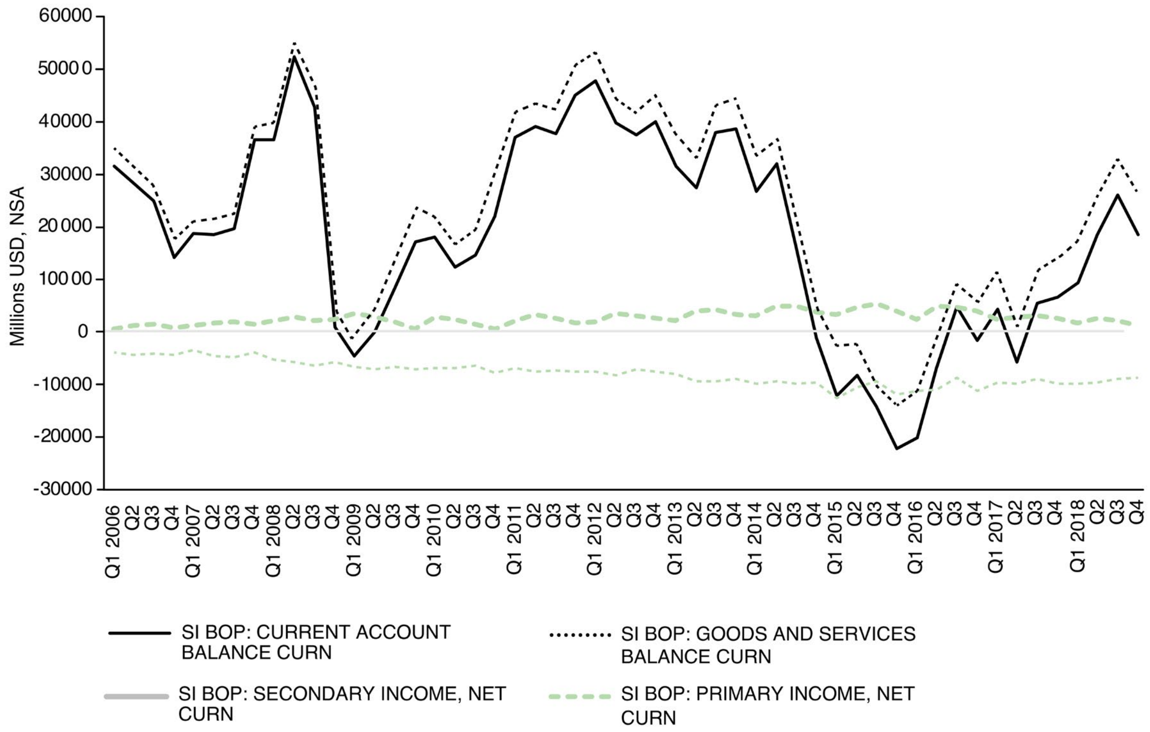
Third, the exchange rate literature discusses that the REER equilibrium level goes up if a country's productivity level exceeds that of the rest of the world. Such an increase in the equilibrium level does not harm a country's competitiveness, as we mentioned previously. For example, higher productivity in advanced economies strengthens their currencies and improves their competitiveness at the same time. From this standpoint, in Figure 2 one can observe the Saudi equilibrium REER level trending downward over the period. This finding may imply that historically, the country's productivity level did not exceed that of the rest of the world, which would raise the REER equilibrium level. Indeed, Panel A in Figure 1 shows that the productivity differential in the oil sector has a downward trend over the period. The productivity differential in the non-oil sector also declined until 2003; it then increased until 2014, before declining thereafter. Theoretically, one can argue that it is not only labor productivity, but also the so-called total factor productivity (TFP) that drives a country's competitiveness. In this regard, Hasanov et al. (2019) calculated that the TFP level and growth rates in Saudi Arabia were almost unchanged, whereas the Penn World Table (Feenstra, Inklaar, and Timmer 2015) shows that TFP was generally decreasing during the period under consideration. This is consistent with Razek and McQuinn's (2021) conclusion that there is room to improve productivity in Saudi Arabia.

Fourth, in some studies, such as IMF (2019) and Suliman and Abid (2020), researchers modeled the Saudi REER movement solely as a function of oil prices, ignoring its other theoretically predicted determinants. Their main argument in doing so was that Saudi Arabia has an oil-based economy, and oil prices shape many macroeconomic indicators, including the REER. However, we note that oil price movements alone do not sufficiently explain Saudi REER movements in recent years. Specifically, both nominal and real oil prices declined after reaching their maximum values in 2012. They continued to decline until 2016, before recovering in 2017 and 2018. Based on the logic of the studies above, the equilibrium REER should follow the same pattern. However, the right-hand graph in Figure 2 portrays a different picture: The equilibrium REER level increased from 2013 to 2015 and then decreased continuously thereafter. The increases from 2013 to 2015 might have been mainly driven by increases in the productivity differential in the non-oil sector and government final consumption over the same period. Similarly, declines from 2016 to 2018 might have been primarily caused by decreases in the productivity differentials in the non-oil and oil sectors and in government final consumption during the same period (see Panel A, Figure 1).

We estimate that in 2018 (the end year of the empirical analysis), the actual REER was 3.5% higher than the equilibrium level. This magnitude of appreciation is not a serious issue for export competitiveness but nonetheless undermines it. Hence, the REER should be adjusted down to the equilibrium. From a decision-making standpoint, it should be acknowledged that reducing the actual REER is not an easy task because the nominal exchange rate is fixed against the USD. Moreover, changing the composition of exports and imports (which can change the relative weights of trade partners and thus, the NEER) takes a long time. In addition, lowering the domestic price level relative to the rest of the world does not seem to be a reasonable policy measure due to domestic reforms and transformations. Moreover, reducing government final consumption spending would slow down the domestic price increase, which would create depreciation pressure on the prevailing REER. However, the reduction in government final consumption would also lower the equilibrium REER, so the gap between these two REER values would not be filled. Additionally, government final consumption expenditure does not seem to be a relevant measure, given that half of it goes to households in the form of employee compensation. To this end, perhaps it would be relevant to increase outflows; that is, increase the level of foreign investments and other assets held by Saudi Arabian authorities and/or decrease the level of foreign liabilities. These would increase NFA, and thus decrease the equilibrium REER level. The outflow would create additional demand for foreign currencies causing these foreign currencies to appreciate against the riyal, which would also contribute to depreciation of the REER. Note that in figures 5 and 6, the Saudi trade balance exceeds the current account, suggesting negative aggregate net primary and secondary income. The figures show that net primary income is relatively small, and that net secondary income and the employee compensation (remittances) component of net primary income is negative.

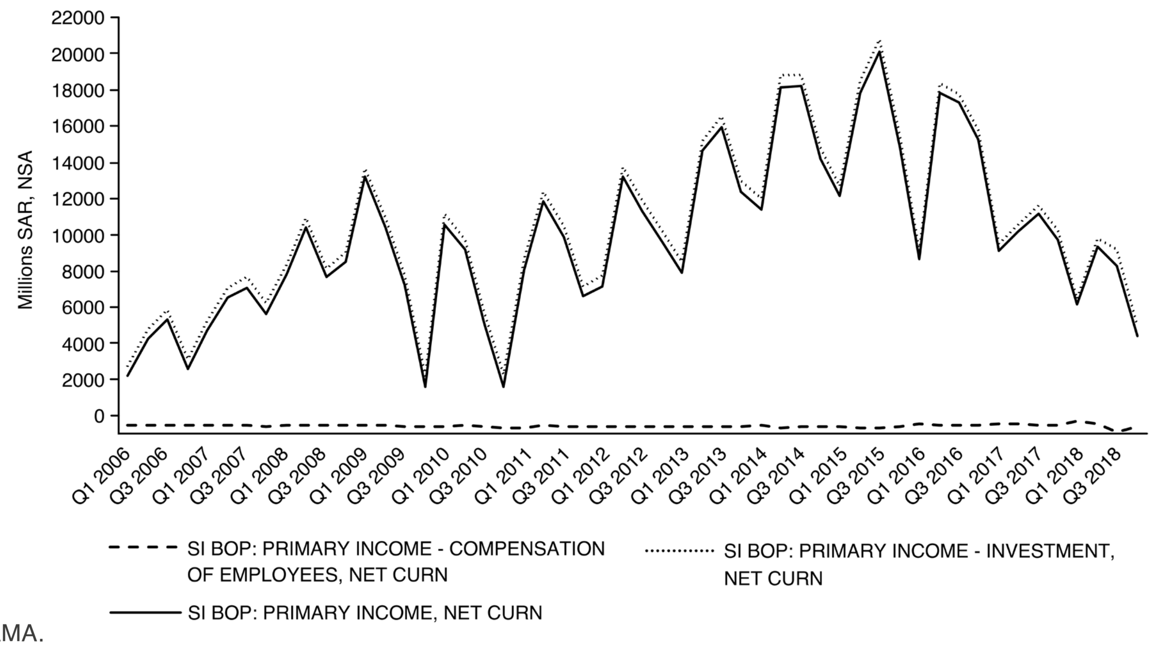
Another remedy would be increasing domestic productivity relative to the rest of the world, which would simultaneously increase competitiveness and the equilibrium REER. This, however, would happen in the medium to long run.

Figure 5. Saudi Arabia's trade and current account balances.



Source: SAMA.

Figure 6. Saudi Arabia's current account: Components of primary income.



Source: SAMA.

Policy Simulation Analysis Using KGEMM

We performed policy simulation analyses for REER-based competitiveness from 2021 to 2025 using an energy (environment) sectors augmented macroeconometric model called the KAPSARC Global Energy Macroeconometric Model (KGEMM). Our aim was to examine the REER-based competitiveness effects of new public investment initiatives announced by the PIF. The initiatives highlighted in the Public Investment Fund Program 2021–2025 (PIF 2021) aim to develop 13 strategic non-oil sectors.

In this section, we first briefly describe the KGEMM and the underlying assumptions for the simulation analyses. Then, we discuss the results of the simulations.

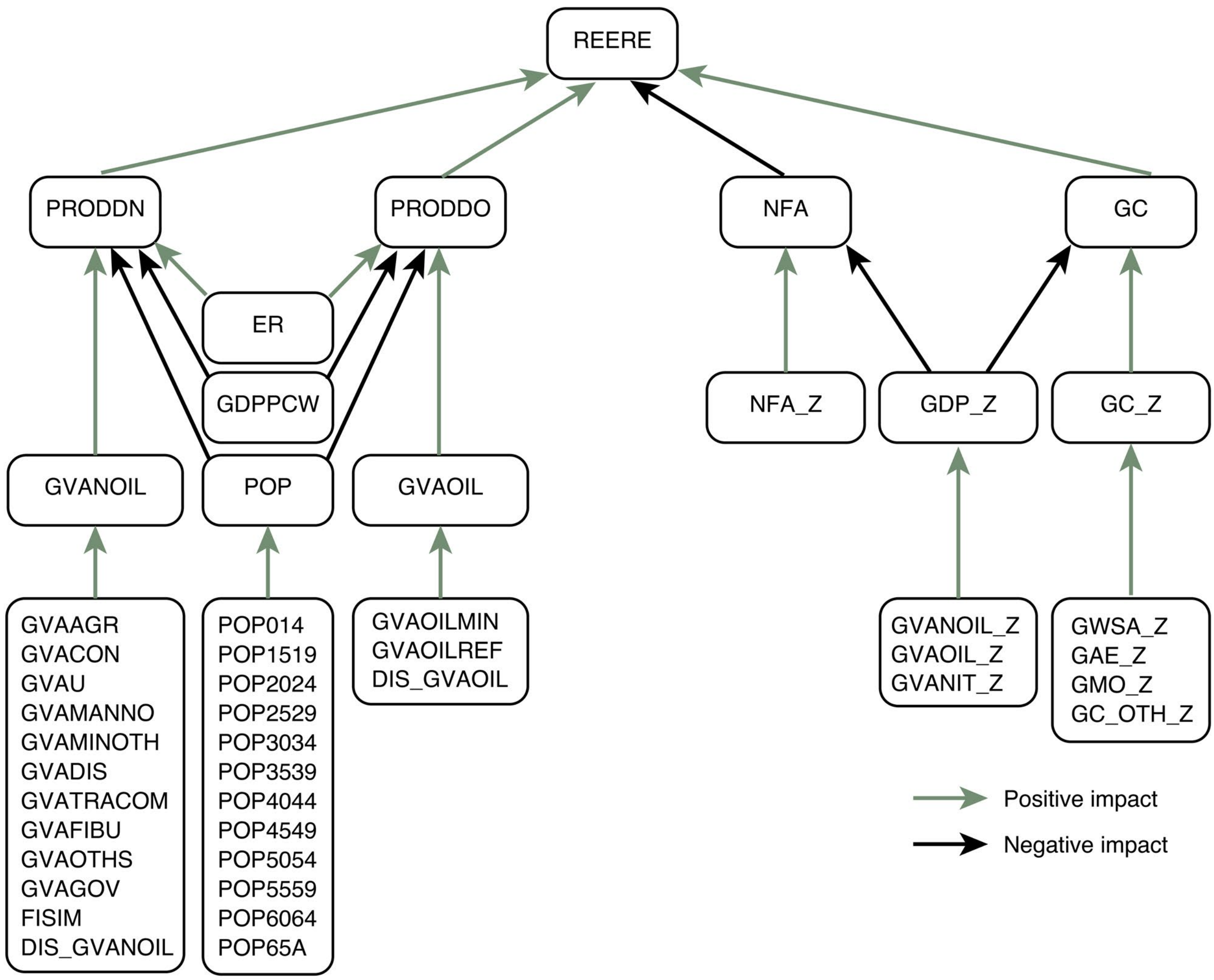
Brief Overview of the KGEMM and REERE Linkages

The KGEMM is a policy tool that assesses the impacts of internal decisions made by Saudi policymakers and changes in the global economy on Saudi Arabia's energy (environment) macroeconomic indicators (Hasanov et al. 2020, 2022). The KGEMM is a general equilibrium, energy (environment) sector augmented model. It is also a semi-structural macroeconometric model, that is, a combination of theory-driven and data-driven approaches. Semi-structural models perform better than purely theory-based models (e.g., dynamic stochastic general equilibrium models or computable general equilibrium models) or purely data-based models (e.g., unrestricted VAR models), as discussed in the literature (see Ballantyne et al. [2020]; Cusbert and Kendall [2018]; Giacomini [2015]; Hendry [2018]; Hendry and Muellbauer [2018]; Jelić and Ravnik [2021]). In addition, KGEMM is a hybrid model, as it incorporates input-output model (IOM) elements, such as intermediate and final demands, into the macroeconometric framework. We briefly describe additional features of the KGEMM in Appendix B. The version of the KGEMM employed here differs from that documented by Hasanov et al. (2020) in the following ways. First, the relationship for the equilibrium real effective exchange rate (REERE in equation (3)), developed in this study has been incorporated into the KGEMM framework. This was done to fulfill the aim of the simulations in this paper and other research and policy analyses in the future. Instead of considering one of the four estimated REER equations in tables 3 and 4, we took the average of the estimated coefficients across the methods and formed the REERE identity.[16] The advantage of this combined approach is that it takes into consideration information from all four estimated equations using different methods. The incorporation of the REERE identity was successful, as the KGEMM was solved consistently. Second, the data have been updated, and most of the behavioral equations have been re-estimated through 2019. Third, the projections account for the impacts of COVID-19 and the low oil price environment. These and other changes in the KGEMM have been documented by Hasanov et al. (2022).

Figure 7 illustrates the first round (equation (3)) and second-round linkages of REER-based competitiveness in the KGEMM framework. In section 3, we described the relationships between REER-based competitiveness (*REERE*) and its selected determinants—namely, relative productivity in the non-oil sector (*PRODDN*) and relative productivity in the oil sector (*PRODDO*) as well as net foreign assets (*NFA*) and government consumption (*GC*), and in section 4 we defined the determinants. Hence, we do not discuss these again here.

Figure 7 further illustrates that the value added in the non-oil sector (*GVANOIL*) is the sum of the value added by 10 non-oil activities, including agriculture (*GVAAGR*), non-oil manufacturing (*GVAMANNO*), construction (*GVACON*), distribution (*GVADIS*) and public services (*GVAGOV*).[17] Value added by the oil sector (*GVAOIL*) is the sum of value added by oil mining (*GVAOILMIN*) and oil refinery (*GVAOILREF*) activities. Total population, a component of productivity, is the sum of 12 population age groups, from children aged 0–14 years (*POP014*) to those over age 65 (*POP65A*). Nominal gross domestic product (*GDP_Z*), which feeds into *NFA* and *GC* in equation (3), is the sum of the value added in the non-oil sectors (*GVANOIL_Z*), oil sector (*GVAOIL_Z*) and by import taxes (*GVANIT_Z*), all in nominal terms. Nominal government consumption (*GC_Z*) is the sum of government wages, salaries and allowances (*GWSA_Z*); government administrative expenses

Figure 7. REER-based competitiveness linkages in KGEMM.



Source: Authors' construction.
Note: → and → indicate positive and negative impacts, respectively.

(*GAE_Z*); government maintenance operations (*GMO_Z*) and other government consumption (*GC_OTH_Z*), all in nominal terms. To ease interpretation, we econometrically estimated sectoral activities as functions of the energy demand of these activities and total demand for these activities, except for oil mining (*GVAOILMIN*), which follows OPEC production agreements and other changes in the international energy markets (see, e.g., Kaufmann et al. 2004, 2008; Wirl and Kujundzic 2004). Total demand is the sum of intermediate demand and final demand. All three are input-output components. Intermediate demand represents interactions among all economic activities, whereas final demand expresses the impacts of final demand elements—that is, government and private investment and consumption as well as exports categorized as oil goods, non-oil goods and services—on economic activities. Details of these and other relationships can be found in Hasanov et al. (2020).

Assumptions for the Simulations and Policy Context

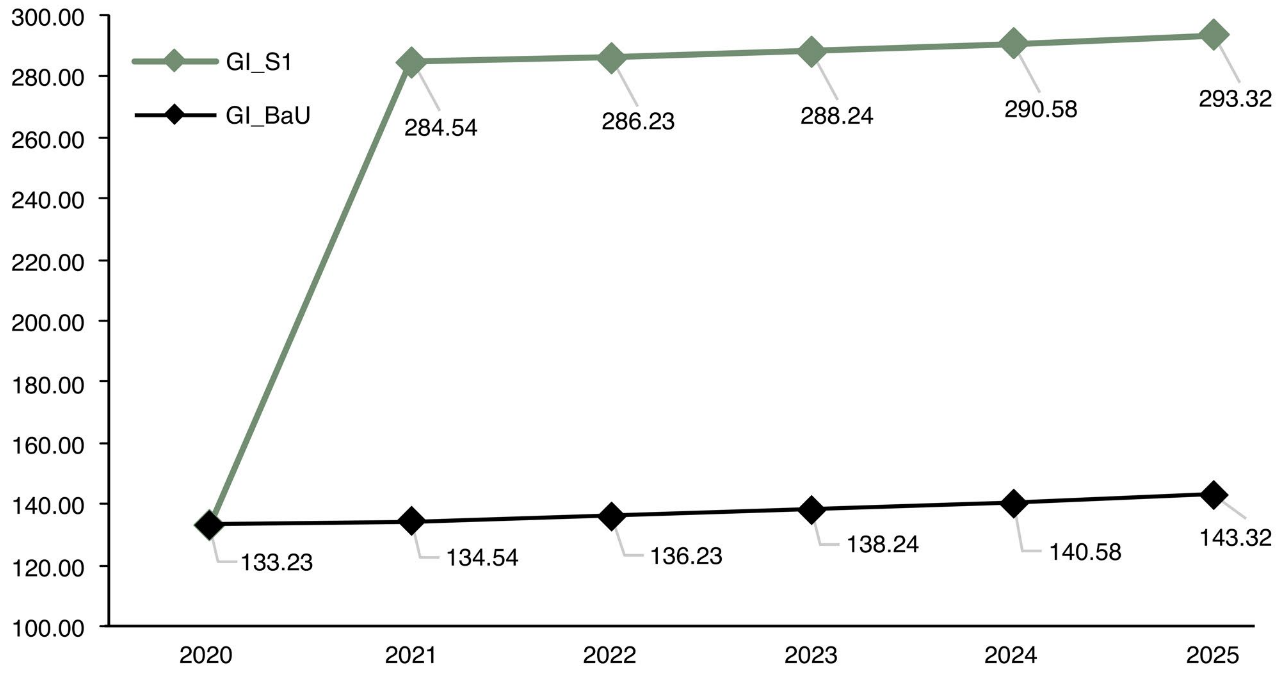
We compared two scenarios: A business-as-usual (BaU) scenario, which simulates the Saudi economy moving into the future and is in line with the KGEMM reference case;[18] and a policy scenario (S1), which simulates what will happen to REER-based competitiveness if the initiatives outlined in the PIF Program (2021–2025) is implemented. Established in 1971, the PIF, one of the leading government agencies in Saudi Arabia, is actively engaged in implementing Saudi Vision 2030 initiatives and achieving its targets. In 2017, the PIF Program (2018–2020) was launched; it was followed by the PIF Program (2021–2025) in 2021. One of the initiatives of the latest program is to invest 150 billion SAR into the Saudi economy each year (PIF 2021). To achieve economic goals and support the development of the national economy, the PIF identified 13 strategic sectors. These are renewables and utilities; aerospace and defense; automotive; transportation and logistics; food and agriculture; construction and building components and services; entertainment, leisure and sports; financial services; real estate; metals and mining; health care; consumer goods and retail; and telecom, media and technology (PIF 2021). The program document describes initiatives, opportunities, progress, and direct strategic objectives that the PIF has established for each of these sectors.

To this end, in S1, we simulate KGEMM to examine what will happen to Saudi REER-based competitiveness if government investments increase by 150 billion SAR more each year from 2021 to 2025 compared to the projected values in the BaU scenario.[19] Obviously, investment is a key driver of economic development, including productivity growth. Therefore, this scenario analysis provides policymakers with useful insights regarding potential improvements in competitiveness associated with government investments. A dedicated analysis of import substitution and local content is beyond the scope of this study. Figure 6 illustrates projected values of government investments for both scenarios (i.e., BaU and S1).

The KGEMM reference case (BaU) projects that government investments will increase from 133.23 billion SAR in 2020 to 143.32 billion SAR in 2025 (red line in Figure 8). Such a projection can be considered reasonable, given that the share of GDP attributed to government investments was, on average, approximately 6% from 1970 to 2020 and approximately 5% in 2019 and 2020; and they are predicted to remain steady at approximately 5% from 2021 to 2025. Considering the PIF strategy, we project government investments will increase by 150 billion SAR each year in S1 compared to the BaU scenario (blue line in Figure 8). Assumptions about other variables as well as technical details of the model and simulations can be obtained from the authors upon request.

Figure 9 illustrates the main transmission channel of the impact of government investment on REER-based competitiveness in the KGEMM framework.[20] As mentioned above, government investment (*GI*) is a component of final demand (*FD*) for each economic activity sector, which in turn is a component of total demand (*TD*) by sector. These TD components, together with energy demand, serve as the explanatory variable in the value added of each economic activity sector, which are aggregated into the non-oil and oil sectors. Lastly, value added by non-oil sector activities (*GVANOIL*) is a component of the relative non-oil sector productivity (*PRODDN*), as expressed in the Data section. The latter is one of the determinants of external price competitiveness (*REERE*), as equation (3) expresses. Thus, expanded

Figure 8. Government investments (in billions SAR, 2010 prices).

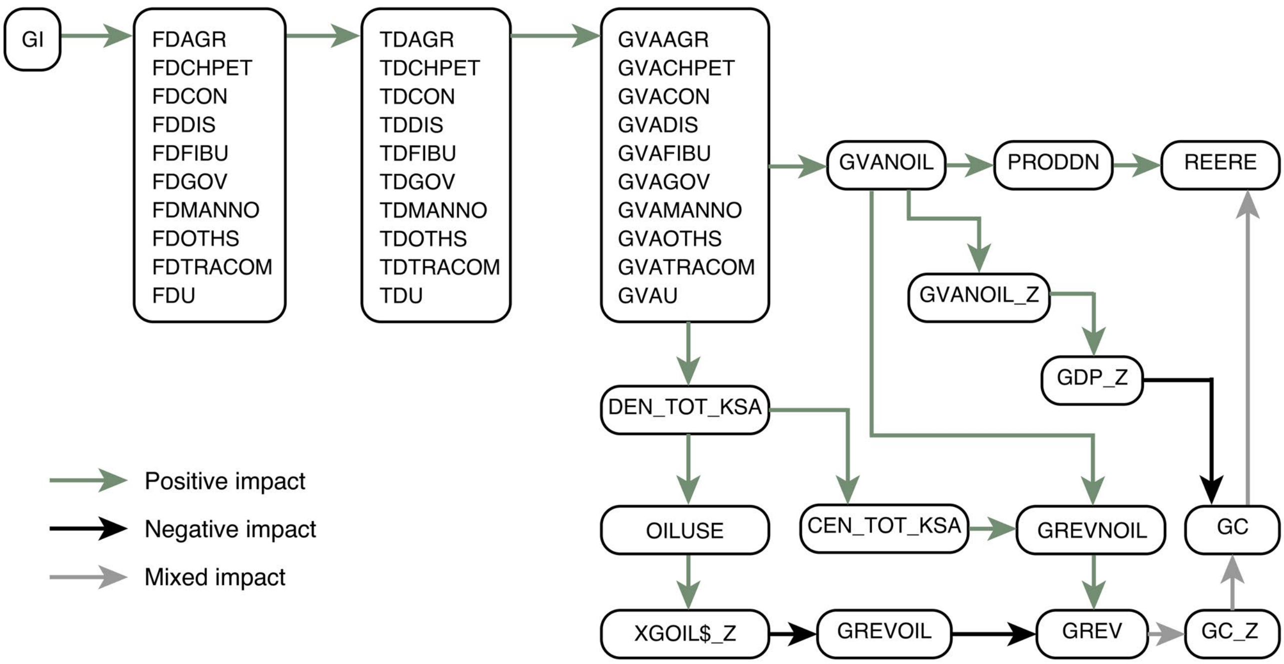


Source: Authors' projections.

government investments will improve external price competitiveness by increasing productivity in the non-oil sector.

Moreover, Figure 9 illustrates that expanding economic activities, driven by increased government investments, will result in more domestic energy consumption (*DEN_TOT_KSA* and *OILUSE* will rise). This will leave less crude and refined oil available for export (i.e., *XGOIL$_Z* decreases). This is because Saudi Arabian oil production is subject to OPEC production agreements (see, e.g., Kaufmann et al. 2008), and renewables constitute a very small share (consistently 0.01% from 1996–2015) of the Kingdom's energy mix (International Energy Agency data; AlGhamdi 2020).[21] As a result, government oil revenues (*GREVOIL*) will decline in S1 compared to BaU, assuming that the export prices of crude and refined oil remain the same in both scenarios. The government's non-oil revenues (*GREVNOIL*) will increase as domestic energy sales (*CEN_TOT_KSA*) and collections from economic activities, such as taxes on income, profits and capital gains, increase. As a result, total government revenues (*GREV*) can decrease with oil revenues and increase with non-oil revenues. These ambiguous (positive and negative) effects will be transmitted to government expenditures, including government consumption (*GC_Z*), as it is financed by government revenues. Increased value added by the non-oil sector (*GVANOIL*) leads to an increase in nominal non-oil value added (*GVANOIL_Z*) and thereby nominal GDP (*GDP_Z*). The increase in the latter causes government consumption (*GC*) to shrink as it is the denominator in the calculation (see the

Figure 9. Transmission channel from government investments to competitiveness.



Source: Authors' construction.
Note: →, → and → indicate positive, negative and mixed impacts , respectively.

Data section). Thus, the impact of government consumption (*GC*) on external price competitiveness (*REERE*) is ambiguous. However, it is likely that the negative impact of oil revenues would overshadow the positive effect of non-oil revenues because the oil sector accounts for a large share of total government revenues (see, e.g., Al Moneef and Hasanov 2020; Hasanov, Javid, and Joutz 2021).

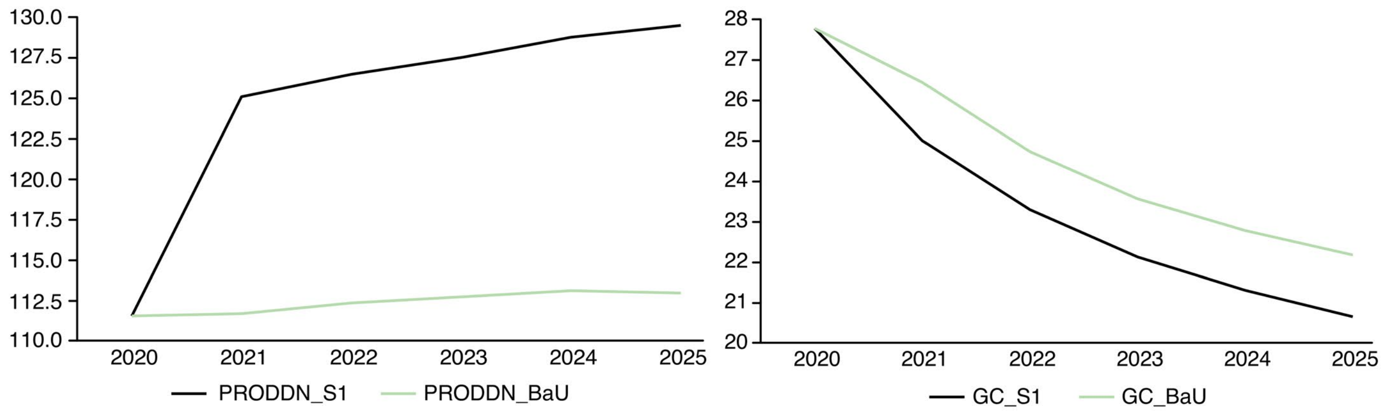
Results of the Projections

Figure 10 illustrates the projected paths of non-oil relative productivity and the size of government consumption. As can be expected from Figure 9 and the associated discussion, relative productivity in the non-oil sector increases, while government consumption size decreases in S1 compared to BaU as a result of increased government investments. Inspection of the model simulation results reveals that increases in the relative productivity of the non-oil sector (*PRODDN*) are entirely driven by expansions in the sector's economic activities (*GVANOIL*) given that the values of its other components—that is, bilateral exchange rate (*ER*), world productivity (*GDPPCW*) and population (*POP*)—do not change from BaU to S1. Numerically, increases in value added by the non-oil sector in S1, compared to BaU, are very similar to the projected increases in relative productivity from 2021 to 2025 shown in Table 6. This implies that increased government investment leads to increased value added by the non-oil sector. With regard to government consumption size (*GC*), declines in S1 are mainly driven by increases in nominal GDP (see Figure 9). Put differently, the size of government consumption decreases as non-oil economic activity and the resulting GDP and nominal GDP expand. The simulation results show that declines in nominal government consumption (GC_Z) in S1 are quite small (i.e., 0.1% in 2021, rising to only 0.3% in 2025) compared to BaU.

Graph A, Figure 10 illustrates that the net effect of these two main drivers (PRODDN and GC) on REER-based competitiveness is positive, as its values in S1 are higher than those in the BaU scenario. REER establishes higher equilibrium levels as a result of increases in government investments over the next five years. This implies that external competitiveness of the Kingdom rises in S1 compared to BaU. The simulation results are consistent with the theoretically predicted relationships between competitiveness, productivity, government consumption and investment as well as the results of the empirical estimations discussed in the previous section.

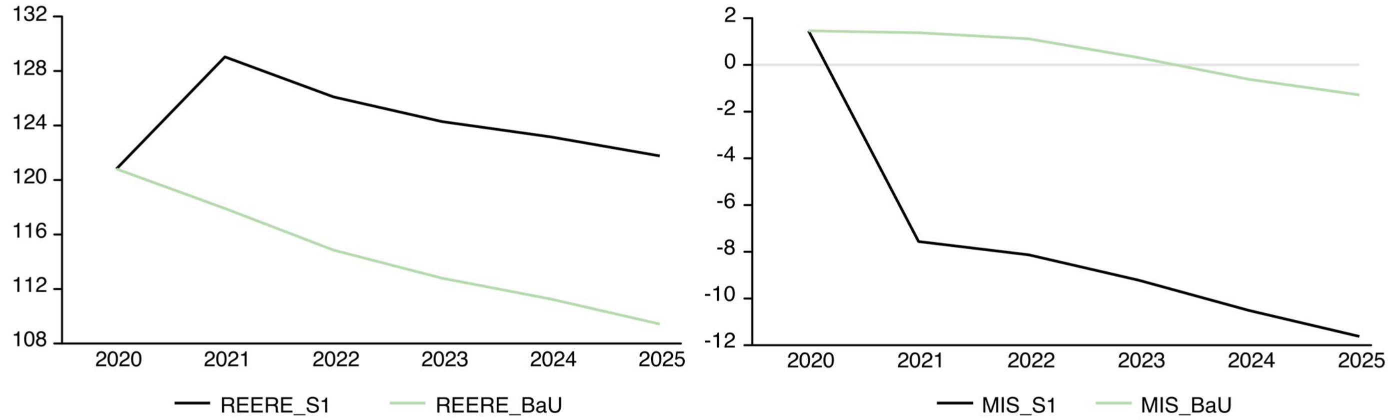
Graph B, Figure 11 illustrates SAR misalignments in both scenarios. It is apparent from the graph that without additional government investments in the economy, misalignments (i.e., deviations of the observed REER from its equilibrium level,

Figure 10. Projected paths of non-oil relative productivity and government consumption size.



Source: Authors' projections.

Figure 11. Projected paths of competitiveness and misalignments.



Source: Authors' projections.

determined by domestic and external fundamentals) show a minimal change from 1.4% in 2021 to -1.3% in 2025, as the red line illustrates. Recall that even in-sample misalignments were in an acceptable range, particularly in recent years (see Figure 3). These misalignment results, from both the estimations and simulations, show that the Kingdom's exchange rate and monetary policies have been quite successful, as the actual/observed REER deviated from its equilibrium path only slightly. When the government (PIF) makes additional investments in the economy in S1, fundamentals of the equilibrium exchange rate (mainly relative productivity in the non-oil sector) increase. This leads to larger misalignments compared to BaU (see Graph B, Figure 11). In other words, driven mainly by productivity increases, the equilibrium path of the REER increases faster than the observable path of the REER, leading to higher values of competitiveness. Numerically, misalignments in S1 change from -7.6% in 2021 to -11.7% in 2025. Note, however, that such misalignments are not harmful, as they are driven by productivity growth, leading to increased competitiveness.

Table 6 reports numerical values from the simulations for the selected variables. We added relative productivity in the non-oil sector (*PRODDN*) to the table as development of the sector is a key goal in Saudi Vision 2030.

Table 6 documents the percentage deviations of S1 values of government investment, non-oil relative productivity and REER-based competitiveness from BaU values. On average, a 108% increase in government investment translates into a 13% increase in productivity, which leads to a 10% appreciation of the equilibrium REER. To this end, the implied average elasticities of the non-oil relative productivity and equilibrium REER with respect to government investments are 0.10 and 0.12, respectively. The implied elasticity might be seen as small. However, this out-of-sample elasticity of 0.10 is quite reasonable given that the in-sample (1971–2020) average elasticity of non-oil relative productivity with respect to government investments is calculated as 0.11.[22] As noted above, two components of non-oil relative productivity—namely, the bilateral nominal exchange rate of

Table 6. Deviations of S1 from BaU, percentage change.

Year	*GI*	*PRODDN*	*REERE*
2021	111.49	11.98	9.48
2022	110.11	12.54	9.84
2023	108.50	13.09	10.23
2024	106.70	13.82	10.75
2025	104.66	14.62	11.33
Average	108.29	13.21	10.33
Implied elasticity		0.10	0.12

Source: Author's calculation.

USD to SAR (*ER*) and productivity in the rest of the world (*GDPPCW*)—are treated as exogenous in the simulations (i.e., their values do not change from BaU to S1). Moreover, projected population values are the same in both scenarios, even though the KGEMM treats total population as an endogenous variable (see Figure 5). Thus, it is the non-oil value added that transmits government investment changes into the relative productivity of the sector (*PRODDN*). We further investigated simulation results for non-oil value added (*GVANOIL*) and found that its implied elasticity with respect to government investment is 0.12 for 2021–2025.[23] Thus, it can be concluded that government investments lead to increased value added and increased productivity in the non-oil sector, thereby increasing the equilibrium level of the REER and Saudi Arabia's external price competitiveness.

As external competitiveness improves as a result of PIF investments in S1 compared to BaU, Saudi Arabia's exports are boosted.[24] Specifically, non-oil exports increase by 14.7% on average, leading to a 0.8% increase in total exports, on average, over 2021-2025 compared to BaU. At the same time, the increase in investments lead to an increase in total imports by an average of 9.9% over the 2021-2025 period compared to BaU. This large increase in imports leads to a deterioration in the trade balance by an average of 12% compared to BaU. This is to be expected, as imports hold a noticeable share in aggregate demand of the country. To avoid a deterioration in the trade balance, or at least reduce its magnitude, one option that authorities may wish to consider is to reduce imports by substituting them, where possible, with domestically produced goods and services. Substitution of imports with domestic production is important for local content development and thus for diversification of the Saudi economy, the main goal of Saudi Vision 2030.

Conclusion and Policy Insights

Among other targets, Saudi Vision 2030 aims to improve Saudi Arabia's ranking on the Global Competitiveness Index from 25 in 2015–2016 to within the top 10 by 2030. It also aims to increase the share of non-oil exports in non-oil GDP from 16% in 2016 to 50% by 2030. Accomplishing these goals requires considerable improvements in Saudi Arabia's competitiveness. This necessitates, among other studies, an investigation to help decision-makers better comprehend the driving forces of Saudi competitiveness.

To this end, we examined the REER as a measure of external price competitiveness and investigated both theoretically predicted and country-specific determinants. Our decision to examine the REER was rooted in the literature, as previous studies have shown that it captures both domestic and global changes. We developed a novel modeling framework for REER-based competitiveness to provide policymakers with broader information regarding Saudi Arabia's historical and projected competitiveness. To obtain robust estimates and derive well-grounded policy insights, we employed different unit root and cointegration tests as well as long-run estimators. As a further robustness check, we expanded our framework with additional variables that might help explain the behavior of the REER. Lastly, we incorporated the estimated REER relationships into the KGEMM, a general equilibrium macroeconometric model, and conducted a policy scenario analysis for 2021–2025 to quantify the competitiveness effects of the PIF's new strategy of investing in 13 strategic sectors.

We found that Saudi external price competitiveness is shaped mainly by the relative productivity of the non-oil sector, followed by government consumption, the relative productivity of the oil sector and NFA. The in-sample misalignment analysis shows that observed REER values remain quite close to equilibrium values, except during abnormal times. This means that appreciation and depreciation from equilibrium values have remained within an acceptable range over the period of investigation. When the government (PIF) makes additional investments in the economy, the fundamentals of the equilibrium exchange rate (primarily, the value added and relative productivity of the non-oil sector) rise. Saudi external price competitiveness improves as a result. Accordingly, misalignments become larger relative to those in the reference (BaU) case. Put differently, the equilibrium path of the REER (that is, Saudi Arabia's competitiveness) shifts upward, that is, improves.

We have derived several policy insights from this research. The main point that policymakers may wish to consider is that productivity growth in the non-oil sector is the main driver of Saudi Arabia's external price competitiveness. Hence, initiatives that can boost this productivity should be implemented. The simulation results show that government investment is a promising initiative in this regard, and investments by the PIF are worth emphasizing. Authorities also may consider increasing government consumption, which can lead to an appreciation of both the observed and equilibrium values of the REER. The extent to which this increase may undermine competitiveness depends on whether the observed values exceed the equilibrium values. Hence, policymakers should be updated regularly regarding REER misalignment. Additionally, with respect to government consumption and investment spending, authorities should consider substituting imports with locally produced goods and services where possible. Increased local content would greatly contribute to diversifying the economy, which is the key strategic goal of Saudi Vision 2030. Another policy consideration relates to NFA, as our findings show that a decrease in NFA leads to an appreciation of the REER. This implies that attracting more foreign investment and other assets from the rest of the world may lead to technological development, the further enhancement of the business environment and an improvement in the economic, financial, and social infrastructure. Yet, it may also lower the country's NFA position and thus appreciate the REER. The former may increase competitiveness. The competitiveness should not deteriorate unless appreciation causes the observed values of the REER to exceed its equilibrium values. This, in turn, necessitates regularly monitoring misalignment and updating the decision-making process accordingly.

Endnotes

[1] Importantly, we focus on the trade-weighted real effective exchange rate (REER), not on bilateral nominal exchange rates. Additionally, we do not discuss fixed versus flexible exchange rate regimes. The dollar peg regime has been advantageous to the Saudi economy and will continue to be so until Saudi Arabia's exports are denominated in a mixture of currencies and the economy is diversified, as discussed by Alkhareif, Barnett, and Qualls (2017) among others. We intend to shed some light on how Saudi Arabia, a prominent oil exporting country, can continue to increase its global competitiveness.

[2] Abdelaziz, Chortareas, and Cipollini (2008) investigated the effects of oil prices and the real exchange rate on stock market prices in Middle Eastern countries, including Saudi Arabia. They did not study the determinants of exchange rate movements. Because their objective was not in line with the question studied here, we did not review their study.

[3] We employ the BEER approach in this study. For a review of the BEER approach and its advantages relative to other competing approaches, please refer to Razek and McQuinn (2021).

[4] Initial estimates showed that oil prices have a statistically significant positive impact on government consumption, regardless of whether real government consumption or its size (share in GDP) is considered. As a result, we empirically show that oil prices have an indirect effect on the REER through government consumption and other variables such as foreign assets.

[5] Razek and McQuinn (2021) graphically showed that oil revenue as a percentage of total government revenue in Saudi Arabia ranged from approximately 56% to 93% between 1980 and 2019.

[6] Government expenditures are materialized through the government budget and Public Investment Fund (PIF). The PIF plays an important role in the economic development and transformation of the Saudi economy in line with Saudi Vision 2030.

[7] In sub-section 6.3, we empirically show that neither openness nor TOT provides additional information that helps explain the behavior of REER when they are included in equation (2).

[8] We also included a time trend in the estimates to investigate whether variables not included in equation (2) could affect the REER in a statistically significant way. The effect was statistically insignificant in all estimates, so the time trend is not included in equation (2).

[9] The starting year of the period is determined by the availability of data for Saudi Arabia.

[10] Differences in the obtained results from the ADF and PP tests may stem from, among other reasons, the fact that they treat the serial correlation issue differently. The ADF uses a parametric approach, while the PP employs a non-parametric method.

[11] First, we set the Schwarz information criterion to identify the optimal lag lengths for the variables, and it selected the ADL (1, 0, 2, 0, 0) specification. However, this specification does not pass the residuals heteroscedasticity test. Hence, we switched to the Akaike information criterion. The long-run coefficients estimated from ADL (1, 0, 2, 0, 0) and those from ADL (2, 0, 2, 2, 0) are very close to each other.

[12] We do not include *OP* and *TOT* in equation (2) together because (a) these two variables are related and can create high multicollinearity, and (b) we already have a small sample size and a large number of regressors.

[13] Socio-economic variables are not strongly stationary, but weakly stationary—that is, their means, variances and covariances are not strictly constant over time. In contrast, variables in the natural sciences exhibit strong stationarity (see, e.g., Gujarati and Porter 2009).

Endnotes

[14] If the estimated coefficients were very different from each other, we would prefer to use the coefficients estimated from the ADL method as it yields more consistent and efficient estimates when sample sizes are small (see Pesaran and Shin 1995).

[15] As the measures of the real international interest rate, we took the world 10-year government bond rate, in percent, from the Oxford Economics Global Economic Model (2021) March database. We then adjusted it with the world GDP deflator for inflation, in percent, from the WDI (World Bank 2021). We used the GDP deflator for inflation because the WDI's (World Bank 2021) CPI inflation data for the world begin in 1981, so using these data would eliminate observations for the year 1980. We took Saudi Arabia's real GDP growth rates from the WDI database (World Bank 2021).

[16] One of the key advantages of KGEMM over other macro (econometric) models is its structure. In the KGEMM structure, estimated behavioral equations (long- or short-run) are converted into their identity representations by using estimated coefficients and residuals. The key advantage of this approach, among others, is that it allows one to change the magnitudes of the coefficients to reflect policy views, which cannot be done if regression equations are used in the model structure. Another advantage is that it allows for an adjustment of the residuals term in a way that the dependent variable follows given the strategic pathways. Allowing for such calibrations makes KGEMM very favorable and flexible for analyzing various announced policies, their initiatives, and targets.

[17] Definitions of the other non-oil sectors can be found in Hasanov et al. (2020). For example, *FISIM* is financial intermediaries, in million Riyal, at 2010 prices, while *DIS_GVANOIL* is the discrepancy term in the *GVANOIL* identity.

[18] Since the KGEMM is a large-scale model containing approximately 1,000 variables, it is beyond the scope of this paper to provide projected values for these variables. However, projections for variables of interest can be obtained from the authors upon request.

[19] Two things are worth-considering: One may treat the PIF investment as a private investment, but we treat it as government investment in this study. We could provide more detailed policy insights if we were able to simulate disaggregated investments into the strategic sectors mentioned above. This presents an opportunity to conduct an interesting study/simulation when such data become available in the future.

[20] We call it the main transmission channel because there are also other channels through which government investment impacts REERE, although such channels are very weak. For example, government investments also increase value added in the oil refinery sector, which in turn leads to a very small increase in the relative productivity of the oil sector.

[21] We assume that the increased energy demand caused by growing economic activity is met by fossil fuels, as the share of renewables is assumed to be the same in both scenarios for the simulation period. However, the KGEMM framework allows us to change this assumption and assume a higher share of renewables in meeting total energy demand in the economy, which can be done in future research.

[22] The elasticity is calculated as the average value of the elasticities, that is, ratios of the growth rates of non-oil relative productivity to the growth rates of government investments in each year for the period 1971–2020.

[23] The elasticity is calculated as the average value of the ratios of the percentage deviations of *GVANOIL* and *GI* in S1 from their respected values in BaU. The respected in-sample average elasticity is calculated to be 0.15 for 1971–2020.

[24] Of course, this assumes demand for an additional increase in exports by the importing trade partners.

[25] Note that the literature uses both long- and short-run equations/models for forecasting or projections purposes. See, for example, discussions in Fanchon and Wendel (1992), Engle and Yoo (1987), Castle et al. (2019),and Engle et al. (1989).

References

Abdelaziz, Mohamed, Georgio Chortareas, and Andrea Cipollini. 2008. “Stock Prices, Exchange Rates, and Oil: Evidence from Middle East Oil-exporting Countries.” *Topics in Middle Eastern and African Economies.* 10. http://meea.sites.luc.edu/volume10/PDFS/Paper%20by%20Abdelaziz&Chortareas&Cipollini.pdf.

Aglietta, Michel, Camille Baulant, and Virginie Coudert. 1998. “Why the Euro Will Be Strong: An Approach Based on Equilibrium Exchange Rates.” *Revue Economique* 49(3):721–731.

Al-Bassam, K. A. 1990. “Money Demand and Supply in Saudi Arabia: An Empirical Analysis.” Ph.D. dissertation, University of Leicester.

Alberola, Enrique, and Daniel Navia. 2007. “Equilibrium Exchange Rates in New EU Members: External Imbalances v. Real Convergence.” Banco de España Working Paper No. 0708.

———. 2008. “Equilibrium Exchange Rates in New EU Members: External Imbalances Versus Real Convergence.” *Review of Development Economics* 12(3):605–619. doi:10.1111/j.1467-9361.2008.00475.

Aleisa, Eisa A., and Sel Dibooĝlu. 2002. “Sources of Real Exchange Rate Movements in Saudi Arabia.” *Journal of Economics and Finance* 26(1):101–110. doi:10.1007/BF02744455.

AlGhamdi, Abeer. 2020. “Saudi Arabia Energy Report.” KAPSARC Discussion Paper No. KS–2020–DP25. doi:10.30573/KS--2020-DP25.

Al-Hamidy, Abdulrahman. 2012. “Aspects of Fiscal/Debt Management and Monetary Policy Interaction: The Recent Experience of Saudi Arabia.” BIS Paper No. 67v. doi:10.2139/ssrn.2205729.

Alkhareif, Ryadh M., William A. Barnett, and John H. Qualls. 2017. “Has the Dollar Peg Served the Saudi Economy Well?” *International Finance and Banking* 4(1):145–162. http://www.macrothink.org/journal/index.php/ifb/article/view/11189.

Al Moneef, H. E. Majid, and Fakhri J. Hasanov. 2020. “Fiscal Multipliers for Saudi Arabia Revisited.” KAPSARC Discussion Paper No. KS–2020–DP21. doi:10.30573/KS--2020-DP21.

Alonso-Gamo, Patricia, Stefania Fabrizio, Vitali Kramarenko, and Qing Wang. 2002. “Lithuania: History and Future of the Currency Board Arrangement.” IMF Working Paper No. 127.

Al Rasasi, Moayad, and Waheed Banafea. 2018. “Estimating Money Demand Function in Saudi Arabia: Evidence from Cash in Advance Model.” SAMA Working Paper WP/18/4.

Al Rasasi, Moayad H., and John H. Qualls. 2019. “Testing for Causality between Oil Prices and Money Supply in Saudi Arabia.” SAMA Working Paper WP/19/04.

Alshehabi, Omar H., and Shuang Ding. 2008. “Estimating Equilibrium Exchange Rates for Armenia and Georgia.” IMF Working Paper No. 08/110.

Altarturi, Basheer H. M., Ahmad Alrazni Alshammri, Tuan Muhd Tau ik Tuan Hussin, and Buerhan Saiti. 2016. “Oil Price and Exchange Rates: A Wavelet Analysis for OPEC Members.” *International Journal of Energy Economics and Policy* 6(3):421–430. http://www.econjournals.com/index.php/ijeep/article/view/2253.

Al-Yousif, Yousif Khalifa. 2000. “Do Government Expenditures Inhibit or Promote Economic Growth: Some Empirical Evidence from Saudi Arabia.” *Indian Economic Journal* 48(2):92–96.

References

Amano, Robert A., and Simon Van Norden. 1998. "Exchange Rates and Oil Prices." *Review of International Economics* 6(4):683–694. doi:10.1111/1467-9396.00136.

Babetskii, Ian, and Balázs Égert. 2005. "Equilibrium Exchange Rate in the Czech Republic: How Good is the Czech BEER?" *Czech Journal of Economics and Finance (Finance and Úver)* 55(5–6):232–252.

Badinger, Harald. 2004. "Austria's Demand for International Reserves and Monetary Disequilibrium: The Case of a Small Open Economy with a Fixed Exchange Rate Regime. *Economica* 71(281):39–55. doi:10.1111/j.0013-0427.2004.00356.x.

Baffes, John, Ibrahim A. Elbadawi, and Stephen A. O'Connell. 1999. "Single-equation Estimation of the Equilibrium Real Exchange Rate." In *Exchange Rate Misalignment Concepts and Measurement for Developing Countries*, edited by Lawrence E. Hinkle and Peter J. Montiel, 405–466. New York: Oxford University Press.

Balassa, Bela. 1964. "The Purchasing Power Parity Doctrine: A Reappraisal." *Journal of Political Economy* 72(6):584–96.

Ballantyne, Alexander, Tom Cusbert, Richard Evans, Rochelle Guttmann, Jonathan Hambur, Adam Hamilton, Elizabeth Kendall, Rachael McCirick, Gabriela Nodari, and Daniel M. Rees. 2020. "MARTIN Has Its Place: A Macroeconometric Model of the Australian Economy." *Economic Record* 96(314):225–251. doi:0.1111/1475-4932.12531.

Bandara, Jayatilleke S. 1991. "Computable general equilibrium models for development policy analysis in LDCs." *Journal of Economic Surveys* 5(1):3-69.

Beenstock, Michael, and Alan Dalziel. 1986. "The Demand for Energy in the U.K.: A General Equilibrium Analysis." *Energy Economics* 8(2):90–98. doi:10.1016/0140-9883(86)90033-2.

Benigno, Gianluca, and Christoph Thoenissen. 2003. "Equilibrium Exchange Rates and Supply-side Performance." *The Economic Journal* 113(486):C103–C124. doi:10.1111/1468-0297.00113.

Brixiova, Zuzana, Balázs Égert, and Thouraya Hadj Amor Essid. 2014. "The Real Exchange Rate and External Competitiveness in Egypt, Morocco and Tunisia." *Review of Middle East Economics and Finance* 10(1):25–51. doi:10.1515/rmeef-2013-0014.

Buenafe, Sheila W., and Celia M. Reyes. 2001. "Alternative Estimation Methodologies for Macro Model: ECM vs. OLS." PIDS Discussion Paper No. 2001-22. http://hdl.handle.net/10419/127770.

Burgess, Robert, Stefania Fabrizio, and Yuan Xiao. 2003. "Competitiveness in the Baltics in the Run-up to EU Accession." IMF Country Report No. 03/114.

Chatah, Mohamad Baha. 1983. "A Monetary Framework for the Saudi Arabian Economy." Ph.D. dissertation, University of Texas at Austin.

Chen, Yu-chin, and Kenneth Rogoff. 2003. "Commodity Currencies." *Journal of International Economics* 60(1):133–160. doi:10.1016/S0022-1996(02)00072-7.

Cheung, Yin-Wong, and Kon S. Lai. 1993. "Finite-sample Sizes of Johansen's Likelihood Ratio Tests for Cointegration." *Oxford Bulletin of Economics and Statistics* 55(3):313–328.

Chinn, Menzie D. 2006. "A Primer on Real Effective Exchange Rates: Determinants, Overvaluation, Trade Flows and Competitive Devaluation." *Open Economies Review* 17(1):115–143. doi:10.1007/s11079-006-5215-0.

Chudik, Alexander, and Joannes Mongardini. 2007. "In Search of Equilibrium: Estimating Equilibrium Real Exchange Rates in Sub-Saharan African Countries." IMF Working Paper No. 07/90. International Monetary Fund. ISBN: 9781451866544.

Clark, Peter B. 1997. "Concepts of Equilibrium Exchange Rates." In *The Globalization of Markets*, edited by Jerome L. Stein, 49–56. Heidelberg: Physica. doi:10.1007/978-3-642-59246-1_4.

Clark, Peter B., and Ronald MacDonald. 1999. "Exchange Rates and Economic Fundamentals: A Methodological Comparison of BEERs and FEERs." In *Equilibrium Exchange Rates*, edited by Ronald MacDonald and Jerome L. Stein. Vol. 69, 285–322. New York: Springer. doi:10.1007/978-94-011-4411-7_10.

———. 2004. "Filtering the BEER: A Permanent and Transitory Decomposition." *Global Finance Journal* 15(1):29–56. doi:10.1016/j.gfj.2003.10.005.

Comunale, Mariarosaria. 2018. "Current Account and Real Effective Exchange Rate Misalignments in Central Eastern EU Countries: An Update Using the Macroeconomic Balance Approach." *Economic Systems* 42(3):414–436. doi:10.1016/j.ecosys.2017.11.002.

Comunale, Mariarosaria, and Francesco Paolo Mongelli. 2020. "The Role of Real, Financial, Monetary and Institutional Factors in Tracking Growth." The World Economic Forum. https://www.weforum.org/agenda/2020/01/real-financial-monetary-institutional-factors-eu-growth/.

Coudert, Virginie, and Cécile Couharde. 2008. "Currency Misalignments and Exchange Rate Regimes in Emerging and Developing Countries." Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) Working Paper No. 2008-07. http://www.cepii.fr/PDF_PUB/wp/2008/wp2008-07.pdf.

Coudert, Virginie, Cécile Couharde, and Valérie Mignon. 2008. "Do Terms of Trade Drive Real Exchange Rates? Comparing Oil and Commodity Currencies." Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) Working Paper No. 2008-32. http://www.cepii.fr/PDF_PUB/wp/2008/wp2008-32.pdf.

Couharde, Cécile, Anne-Laure Delatte, Carl Grekou, Valérie Mignon, and Florian Morvillier. 2018. "EQCHANGE: A World Database on Actual and Equilibrium Effective Exchange Rates." *International Economics* 156:206–230. doi:10.1016/j.inteco.2018.03.004.

Cusbert, Tom, and Elizabeth Kendall. 2018. "Meet MARTIN, the RBA's New Macroeconomic Model." *Australian Reserve Bank Bulletin* (March):31–44.

Darrat, Ali F. 1984. "The Money Demand Relationship in Saudi Arabia: An Empirical Investigation. *Journal of Economic Studies* 11(3):43–50. doi:10.1108/eb002582.

———. 1986. "The Demand for Money in Some Major OPEC Members: Regression Estimates and Stability Results." *Applied Economics* 18(2):127-142. doi:10.1080/00036848600000019.

References

Dibooglu, Selahattin, and Walter Enders. 1995. "Multiple Cointegrating Vectors and Structural Economic Models: An Application to the French Franc/U.S. Dollar Exchange Rate." *Southern Economic Journal* 61(4):1098–1116. doi:10.2307/1060743.

Dickey, David A., and Wayne A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74(366a):427–431. doi:10.1080/01621459.1979.10482531.

Dreger, Christian, and Massimiliano Marcellino. 2007. "A Macroeconometric Model for the Euro Economy." *Journal of Policy Modeling* 29(1):1–13. doi:10.1016/j.jpolmod.2006.01.007.

Eckstein, Zvi, and Amit Friedman. 2011. "The Equilibrium Real Exchange Rate for Israel." In *The Influence of External Factors on Monetary Policy Frameworks and Operations*, BIS Paper No. 57, 201–14. Bank for International Settlements.

Égert, Balázs, Amina Lahrèche-Révil, and Kirsten Lommatzsch. 2004. "The Stock-flow Approach to the Real Exchange Rate of CEE Transition Economies." Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) No. 2004-15.

El Mallakh, Ragaei, and Dorothea H. El Mallakh. 1982. *Saudi Arabia: Energy, Developmental Planning, and Industrialization*. Lexington: Lexington Books.

Elshurafa, Amro, Fakhri Hasanov, and Lester C. Hunt. 2022. "Macroeconomic, Energy, and Emission Effects of Solar PV Deployment at Utility and Distributed Scales in Saudi Arabia." https://ssrn.com/abstract=4229800 or http://dx.doi.org/10.2139/ssrn.4229800

Enders, Walter. 2015. *Applied Econometrics Time Series,* fifth edition. Hoboken, New Jersey: Wiley.

Enders, Walter, and Junsoo Lee. 2012a. "A Unit Root Test Using a Fourier Series to Approximate Smooth Breaks." *Oxford Bulletin of Economics and Statistics* 74(4):574–599. doi:10.1111/j.1468-0084.2011.00662.

———. 2012b. "The Flexible Fourier Form and Dickey–Fuller Type Unit Root Tests." *Economics Letters* 117(1):196–199. doi:10.1016/j.econlet.2012.04.081.

Engle, Robert F., and Clive W.J. Granger. 1987. "Cointegration and Error-correction: Representation, Estimation, and Testing. *Econometrica* 55(2):251–276. doi:10.2307/1913236.

Engle, Robert F., Clive W.J. Granger, and Jeff J. Hallman.1989. "Merging short-and long-run forecasts: An application of seasonal cointegration to monthly electricity sales forecasting." *Journal of Econometrics* 40(1):45-62.

Engle, Robert F., and Byung Sam Yoo. 1987. "Forecasting and testing in co-integrated systems." *Journal of Econometrics* 35(1):143-159.

European Commission. 2002. "Price and Cost Competitiveness: Technical Appendix." Directorate-General for Economic and Financial Affairs, Brussels.

Fair, Ray C. 1979. "An Analysis of the Accuracy of Four Macroeconometric Models." *Journal of Political Economy* 87(4):701–718.

———. 1993. "Testing Macroeconometric Models." *American Economic Review* 83(2):287–293.

Fanchon, Phillip, and Jeanne Wendel. 1992. “Estimating VAR models under non-stationarity and cointegration: alternative approaches for forecasting cattle prices.” *Applied Economics* 24(2):207-217.

Fasano, Ugo, and Qing Wang. 2001. “Fiscal Expenditure Policy and Non-oil Economic Growth: Evidence from GCC Countries.” IMF Working Paper No. 2001-195. doi:10.5089/9781451859911.001.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. “The Next Generation of the Penn World Table.” *American Economic Review* 105(10):3150–3182. https://www.rug.nl/ggdc/productivity/pwt/?lang=en.

Ferraro, Domenico, Kenneth Rogoff, and Barbara Rossi. 2015. “Can Oil Prices Forecast Exchange Rates? An Empirical Analysis of the Relationship Between Commodity Prices and Exchange Rates.” *Journal of International Money and Finance* 54:116–141. doi:10.1016/j.jimonfin.2015.03.001.

Fidora, Michael, Claire Giordano, and Martin Schmitz. 2021. “Real Exchange Rate Misalignments in the Euro Area.” *Open Economies Review* 32(1):71–107. doi:10.1007/s11079-020-09596-1.

Giacomini, Raffaella. 2015. “Economic Theory and Forecasting: Lessons from the Literature.” *Journal of Econometrics* 18:C22–C41. doi:10.1111/ectj.12038.

Giordano, Claire. 2019. “How Frequent a BEER? Assessing the Impact of Data Frequency on Real Exchange Rate Misalignment Estimation.” Bank of Italy Occasional Paper 522. Bank of Italy, Rome.

Granger, Clive W.J., and Paul Newbold. 1974. “Spurious Regressions in Econometrics.” *Journal of Econometrics* 2(2):111–120.

Grekou, Carl. 2018. “EQCHANGE Annual Assessment 2018.” Centre D’Etudes Prospectives et D’Informations Internationales (CEPII) Working Paper No. 2018-23. http://www.cepii.fr/PDF_PUB/wp/2018/wp2018-23.pdf

Gujarati, Damodar N., and Dawn C. Porter. 2009. *Basic Econometrics*, fifth edition. New York: McGraw-Hill.

Habib, Maurizio Michael, and Margarita M. Kalamova. 2007. “Are There Oil Currencies? The Real Exchange Rate of Oil Exporting Countries.” ECB Working Paper No. 839. doi:10.2139/ssrn.1032834.

Hasanov, Fakhri. 2010. “The Impact of Real Oil Price on Real Effective Exchange Rate: The Case of Azerbaijan.” DIW Berlin Discussion Paper No. 1041. doi:10.2139/ssrn.1784305.

———. 2019. “Theoretical Framework for Industrial Electricity Consumption Revisited: Empirical Analysis and Projections for Saudi Arabia.” KAPSARC Discussion Paper No. KS-2019-DP66. doi:10.30573/ks--2019-dp66.

Hasanov, Fakhri, Muhammad Javid, and Frederick L. Joutz. 2021. “Saudi Non-oil Exports Before and After COVID-19: Historical Impacts of Determinants and Scenario Analysis.” KAPSARC Discussion Paper No. KS-2020-DP09. doi: 10.30573/KS--2021-DP09.

Hasanov, Fakhri J., Nader AlKathiri, Saad A. Alshahrani, and Ryan Alyamani. 2021. The impact of fiscal policy on non-oil GDP in Saudi Arabia. *Applied Economics* 54(7):793–806. doi:10.1080/00036846.2021.1966370.

References

Hasanov, Fakhri, Fred L. Joutz, Jeyhun I. Mikayilov, and Muhammad Javid. 2020. "KGEMM: A Macroeconometric Model for Saudi Arabia." KAPSARC Discussion Paper No. KS-2020-DP04. doi:10.30573/KS--2020-DP04.

Hasanov, Fakhri J., Frederick L. Joutz, Jeyhun I. Mikayilov, and Muhammad Javid. 2022. "A Macroeconometric Model for Saudi Arabia. A Case Study on the World's Largest Oil Exporter". *SpringerBriefs in Economics*. https://doi.org/10.1007/978-3-031-12275-0.

Hasanov, Fakhri J., Brantley Liddle, Jeyhun I. Mikayilov, and Carlo Andrea Bollino. 2019. "How Total Factor Productivity Drives Long-run Energy Consumption in Saudi Arabia." In *Energy and Environmental Strategies in the Era of Globalization*, edited by Muhammad Shahbaz and Daniel Balsalobre, 195–220. New York: Springer.

Hasanov, Fakhri, Jeyhun Mikayilov, Cihan Bulut, Elchin Suleymanov, and Fuzuli Aliyev. 2017. "The Role of Oil Prices in Exchange Rate Movements: The CIS Oil Exporters. *Economies* 5(2):13. doi:10.3390/economies5020013.

Hemrit, Wael, and Noureddine Benlagha. 2018. "The Impact of Government Spending on Non-oil-GDP in Saudi Arabia (Multiplier Analysis)." *International Journal of Economics and Business Research* 15(3):350–372. doi:10.1504/IJEBR.2018.091050.

Hendry, David F. 2018. "Deciding Between Alternative Approaches in Macroeconomics." *International Journal of Forecasting* 34(1):119–135. doi:10.1016/j.ijforecast.2017.09.003.

Hendry, David F, and John N. J. Muellbauer. 2018. "The Future of Macroeconomics: Macro Theory and Models at the Bank of England." *Oxford Review of Economic Policy* 34(1-2):287–328. doi:10.1093/oxrep/grx055.

Castle, Jennifer, David F. Hendry, and Michael P. Clements. 2019. *Forecasting*. Yale University Press.

International Monetary Fund. n.d. "What is real effective exchange rate (REER)?" http://datahelp.imf.org/knowledgebase/articles/537472-what-is-real-effective-exchange-rate-reer.

———. 2011. "Saudi Arabia: 2011 Article IV Consultation: Staff Report; Public Information Notice on the Executive Board Discussion." IMF Staff Country Reports No. 11/292. doi:10.5089/9781463904272.002.

———. 2018. "Saudi Arabia: 2018 Article IV Consultation - Press Release and Staff Report." IMF Country Report No. 18/263. doi:10.5089/9781484374269.002.

———. 2019. "Saudi Arabia: 2019 Article IV Consultation - Press Release and Staff Report." IMF Country Report No. 19/290. doi:10.5089/9781513513447.002.

Javed, Sajid Amin, Wajid Ali, and Vaqar Ahmed. 2016. "Exchange Rate and External Competitiveness: A Case of Pakistan." SDPI Monetary Policy Brief, Policy Paper No. 41. doi:10.13140/RG.2.2.26212.58244

Jelić, Ozana Nadoveza, and Rafael Ravnik. 2021. "Introducing Policy Analysis Croatian MAcroecoNometric Model (PACMAN)." Croatian National Bank.

Johansen, Søren. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 12(2-3):231–254. doi:10.1016/0165-1889(88)90041-3.

———. 1992. "Cointegration in Partial Systems and the Efficiency of Single-equation Analysis." *Journal of Econometrics* 52(3):389–402. doi:10.1016/0304-4076(92)90019-N.

Johansen, Søren, and Katarina Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration—with Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52(2):169–210.

Juselius, Katarina. 2006. "The Cointegrated VAR Methodology." In *Oxford Research Encyclopedia of Economics and Finance*. doi:10.1093/acrefore/9780190625979.013.247.

Kaufmann, Robert K., Andrew Bradford, Laura H. Belanger, John P. Mclaughlin, and Yosuke Miki. 2008. "Determinants of OPEC Production: Implications for OPEC Behavior." *Energy Economics* 30(2):333–351. doi:10.1016/j.eneco.2007.04.003.

Kaufmann, Robert K., Stephane Dees, Pavlos Karadeloglou, and Marcelo Sanchez. 2004. "Does OPEC Matter? An Econometric Analysis of Oil Prices." *Energy Journal* 25(4):67–90. doi:10.5547/ISSN0195-6574-EJ-Vol25-No4-4.

Khan, Muhammad. A., and Musleh ud Din. 2011. "A dynamic macroeconometric model of Pakistan's economy." PIDE Working Paper.

Krugman Paul R., Maurice Obstfeld, and Marc Melitz. 2015. *International Economics: Theory and Policy*, tenth edition. London: Pearson Series in Economics.

Lauro, Bernadette, and Martin Schmitz. 2013. "Euro Area Exchange Rate-based Competitiveness Indicators: A Comparison of Methodologies and Empirical Results." *Proceedings of the Sixth IFC Conference on Statistical Issues and Activities in a Changing Environment* 36:325–339. https://econpapers.repec.org/bookchap/bisbisifc/36-21.htm.

Leichter, Jules, Cristina Mocci, and Stefania Pozzuoli. 2010. "Measuring External Competitiveness: An Overview." Government of the Italian Republic, Ministry of Economy and Finance, Department of the Treasury Working Paper No. 2. doi:10.2139/ssrn.1628111.

Lommatzsch, Kirsten, and Silke Tober. 2004. "What is Behind the Real Appreciation of the Accession Countries' Currencies? An Investigation of the PPI-based Real Exchange Rate." *Economic Systems* 28(4):383–403. doi:10.1016/j.ecosys.2004.11.001.

Looney, Robert E. 1985. "Pre-revolutionary Iranian Economic Policy Making: An Optimal Control Based Assessment." *Economic Modelling* 2(4):357–368. doi:10.1016/0264-9993(85)90032-X.

———. 1986. "Socio-economic Tradeoffs in Saudi Arabia's Third Five Year Plan (1980–1985)." *Socio-Economic Planning Sciences* 20(4):181–192. doi:10.1016/0038-0121(86)90009-1.

———. 1988. "Saudi Arabia's Fiscal Options: 1986–1992." *Socio-Economic Planning Sciences* 22(3):109–123. doi:10.1016/0038-0121(88)90012-2.

———. 1989. "Saudi Arabia's Development Strategy: Comparative Advantage vs. Sustainable Growth." Defense Technical Information Center, Accession No. ADA528520. Monterey, CA: Naval Postgraduate School.

References

MacDonald, Ronald, and Luca A. Ricci. 2002. "Purchasing Power Parity and New Trade Theory." IMF Working Paper No. 02/32. doi:10.5089/9781451845129.001.

MacKinnon, James G., Alfred A. Haug, and Leo Michelis. 1999. "Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration." *Journal of Applied Econometrics* 14:563–77. doi:10.1002/(SICI)1099-1255(199909/10)14:5<563::AID-JAE530>3.0.CO;2-R.

Meshulam, Dan, and Peter Sanfey. 2019. "The Determinants of Real Exchange Rates in Transition Economies." *European Bank for Reconstruction and Development Working Paper Series* 228. https://www.ebrd.com/publications/working-papers/real-exchange-rates

Mozayani, Amir H., and Sanaz Parvizi. 2016. "Exchange Rate Misalignment in Oil Exporting Countries (OPEC): Focusing on Iran." *Iranian Economic Review* 20(2):261–376. doi:10.22059/ier.2016.58802.

Musila, Jacob Wanjala. 2002. "An Econometric Model of the Malawian Economy." *Economic Modelling* 19(2):295–330. doi:10.1016/S0264-9993(01)00065-7.

Nagayasu, Jun. 2017. "Global and Country-specific Movements in Real Effective Exchange Rates: Implications for External Competitiveness." *Journal of International Money and Finance* 76:88–105. doi:10.1016/j.jimonfin.2017.05.005.

Narayan, Paresh Kumar. 2005. "The Saving and Investment Nexus for China: Evidence from Cointegration Tests." *Applied Economics* 37(17):1979–1990.

Nikas, Alexandros, Haris Doukas, and Andreas Papandreou. 2019. "A Detailed Overview and Consistent Classification of Climate-economy Models." In *Understanding Risks and Uncertainties in Energy and Climate Policy*, edited by Haris Doukas, Alexandros Flamos, and Jenny Lieu, 1–54. New York: Springer.

Orszaghova, Lucia, Li Savelin, and Willem Schudel. 2012. "External Competitiveness of EU Candidate Countries." ECB Occasional Paper No. 141. https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp141.pdf

Oxford Economics Group. 2021. "Oxford Economics Global Economic Model Database." March release [Dataset]. https://www.oxfordeconomics.com/service/subscription-services/macro/global-economic-model/.

Perron, Pierre. 1990. "Testing for a Unit Root in a Time Series with a Changing Mean." *Journal of Business & Economic Statistics* 8(2):153–162. doi:10.1080/07350015.1990.10509786.

Perron, Pierre, and Timothy J. Vogelsang. 1992a. "Nonstationarity and Level Shifts with an Application to Purchasing Power Parity." *Journal of Business & Economic Statistics* 10(3):301–320. doi:10.1080/07350015.1992.10509907.

———. 1992b. "Testing for a Unit Root in a Time Series with a Changing Mean: Corrections and Extensions." *Journal of Business & Economic Statistics* 10(4):467–470. doi:10.1080/07350015.1992.10509923.

Pesaran, M. Hashem, and Yongcheol Shin. 1995. "An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis." *Cambridge Working Papers in Economics*. Faculty of Economics, University of Cambridge. doi:10.1017/CCOL0521633230.011.

Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics* 16(3):289–326. doi:10.1002/jae.616.

Peters, Dominique. 2010. "Price Competitiveness in Central and Eastern Europe—A Case Study for Transition Economies." IMK Study No. 1/2010. IMK at the Hans Boeckler Foundation, Macroeconomic Policy Institute.

Phillips, Peter C. B., and Pierre Perron. 1988. "Testing for a Unit Root in Time Series Regression." *Biometrika* 75(2):335–346. doi: 10.1093/biomet/75.2.335.

Public Investment Fund (PIF). 2021. "Public Investment Fund Program 2021-2025." https://www.pif.gov.sa/VRP%202025%20Downloadables%20EN/PIFStrategy2021-2025-EN.pdf

Razek, Noha H. A., and Brian McQuinn. 2021. "Saudi Arabia's Currency Misalignment and International Competitiveness, Accounting for Geopolitical Risks and the Super-contango Oil Market." *Resources Policy* 72:102057. doi:10.1016/j.resourpol.2021.102057.

Reimers, Hans-Eggert. 1992. "Comparisons of Tests for Multivariate Cointegration." *Statistical Papers* 33(1):335–359. doi:10.1007/BF02925336.

Reinsel, Gregory C., and Sung K. Ahn. 1992. "Vector Autoregressive Models with Unit Roots and Reduced Rank Structure: Estimation, Likelihood Ratio Test, and Forecasting. *Journal of Time Series Analysis* 13(4):353–375. doi:10.1111/j.1467-9892.1992.tb00113.x.

Rodrik, Dani. 2007. "The Real Exchange Rate and Economic Growth: Theory and Evidence." Working paper, Harvard University. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.554.1195&rep=rep1&type=pdf

Samuelson, Paul A. 1964. "Theoretical Notes on Trade Problems." *Review of Economics and Statistics* 46: 145–54. doi:10.2307/1928178.

Saudi Arabian Monetary Authority (SAMA). 2018. "Yearly Statistics." https://www.sama.gov.sa/en-US/EconomicReports/Pages/YearlyStatistics.aspx

Suliman, Tilal Hassen Mohammed, and Mehdi Abid. 2020. "The Impacts of Oil Price on Exchange Rates: Evidence from Saudi Arabia." *Energy Exploration & Exploitation* 38(5):2037–2058. doi:10.1177/0144598720930424.

United Nations Conference on Trade and Development (UNCTAD). 2012. "Development and Globalization: Facts and figures 2012." United Nations Conference on Trade and Development, New York. https://unctad.org/system/files/official-document/webgdsdsi2012d2_en.pdf.

Vogelsang, Timothy J., and Pierre Perron. 1998. "Additional Tests for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time." *International Economic Review* 39(4):1073–1100. doi:10.2307/2527353.

Welfe, Władysław. 2013. *Macroeconometric Models*. New York: Springer.

References

Weyerstrass, Klaus, Reinhard Neck, Dmitri Blueschke, Boris Majcen, Andrej Srakar, and Miroslav Verbič. 2018. "SLOPOL10: a macroeconometric model for Slovenia." *Economic and Business Review* 20(2): 269-302.

Weyerstrass, Klaus, and Reinhard Neck. 2007. "SLOPOL6: a macroeconometric model for Slovenia." *International Business & Economics Research Journal* (IBER) 6(11).

Wickens, Michael. 1995. "Real business cycle analysis: a needed revolution in macroeconometrics." *The Economic Journal* 105(433): 1637-1648.

Wirl, Franz, and Azra Kujundzic. 2004. "The Impact of OPEC Conference Outcomes on World Oil Prices 1984–2001." *Energy Journal* 25(1):45–62. doi:10.5547/ISSN0195-6574-EJ-Vol25-No1-3.

World Bank. 2017. "Net Foreign Assets." current LCU. [Dataset]. http://data.worldbank.org/indicator/FM.AST.NFRG.CN

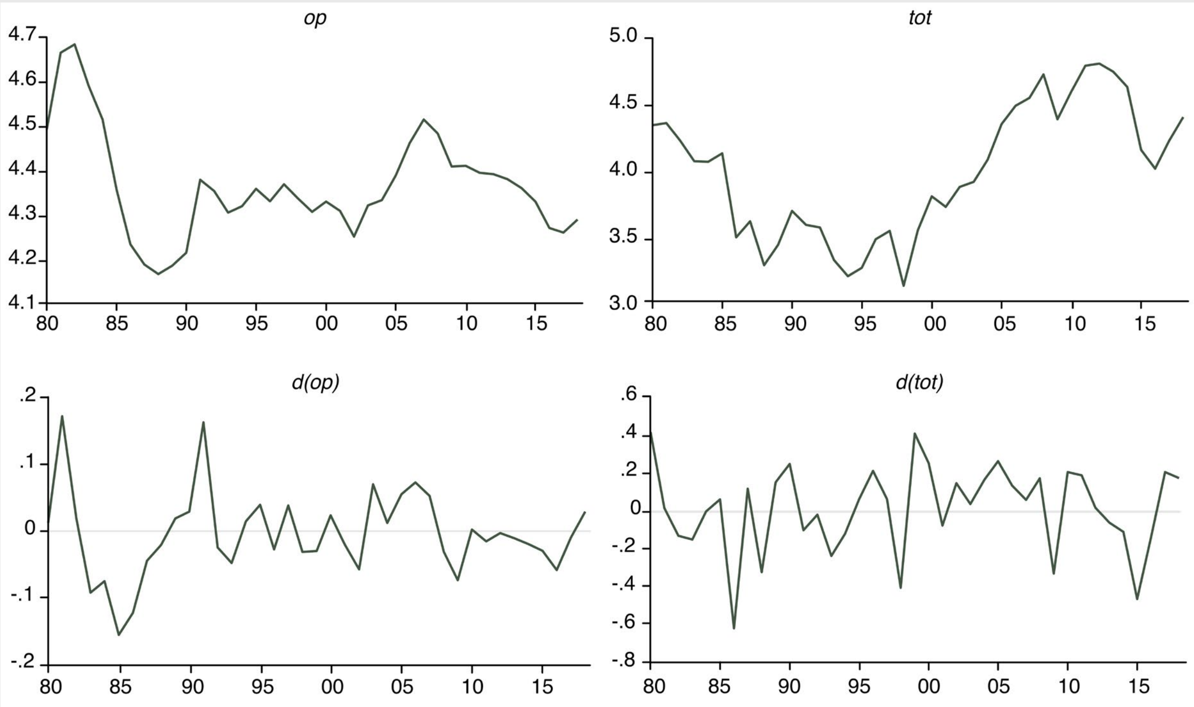
———. 2021. "World Development Indicators Database." [Dataset]. https://datatopics.worldbank.org/world-development-indicators/

Appendix A. Description and test of the variables used in the additional robustness checks

Trade openness (*OP*) is calculated as the percentage share of the sum of exports and imports in GDP using the conventional approach in the literature. All three variables are in millions of 2010 riyals and taken from GaStat. Terms of trade (*TOT*) is constructed as the percentage ratio of the price of exports to the price of imports. The price of exports (imports) is calculated as the percentage ratio of nominal exports (imports) to real exports (imports). Both nominal exports and nominal imports are in millions of riyals and collected from GaStat. Figure A1 below illustrates the logarithmic transformation of the variables, that is, *op* and *tot*, and their first differences.

We performed the ADF and PP tests on *op* and *tot*. We set the maximum lag order at two and selected the optimal lag based on the Schwarz information criteria in the ADF tests of the variables. Because the trend was insignificant in the ADF and PP tests of *op* and *tot*, we excluded it from the test equations. Similarly, the intercept term was insignificant in the ADF and PP tests of *d(op)* and *d(tot)*. Therefore, we dropped it. The test results, which are not reported here but are available from the authors upon request, indicate that *op* and *tot* are unit root processes (i.e., non-stationary), whereas *d(op)* and *d(tot)* are stationary. Thus, we concluded that *op* and *tot* are I(1) variables.

Figure A1. Time profiles of *op* and *tot*.

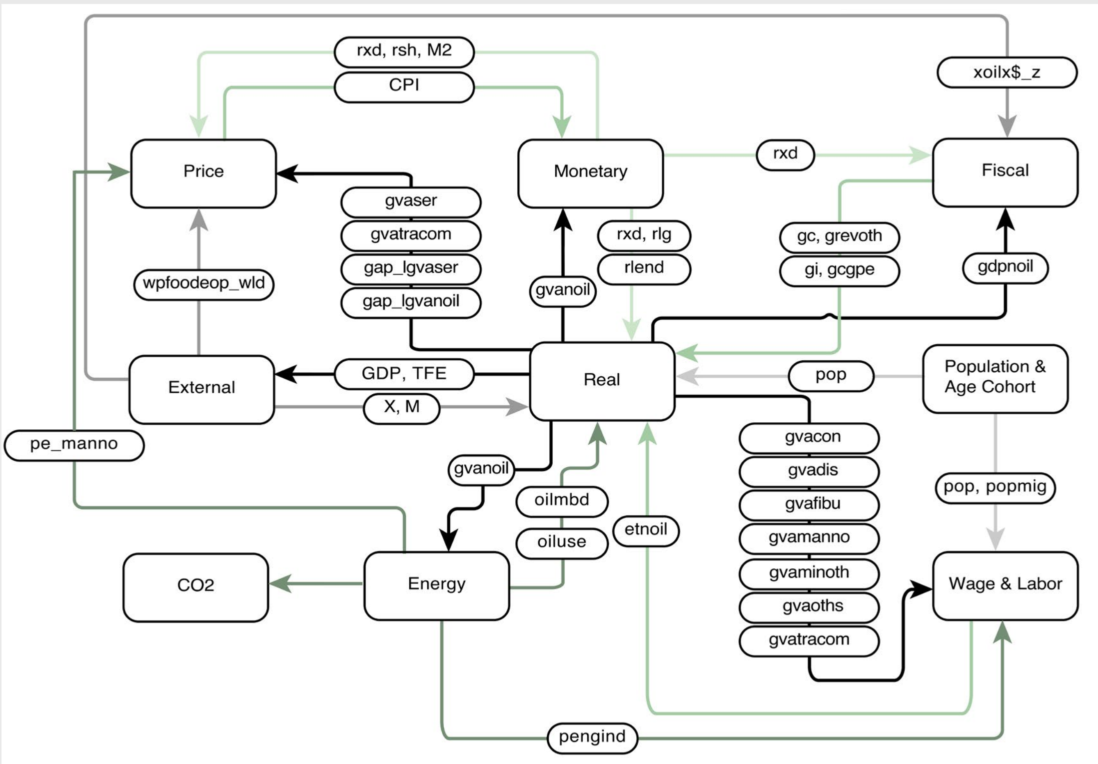


Source: Authors' construction

Appendix B. Additional features of the KGEMM

Here, we provide a brief description of the KGEMM. For details about the model, see Hasanov et al. (2020, 2022). In Figure B1, there are nine blocks interacting with each other to represent Saudi Arabia's macroeconomic and energy (environmental) linkages. These are based on about 1,000 annual time series variables, classified as endogenous or exogenous, and more than 330 behavioral equations and identities. The exogenous variables mostly represent domestic policy, global energy and the global economy. The endogenous variables are determined by behavioral equations or identities constructed primarily based on the System of National Accounts. The behavioral relationships among the variables are modeled using cointegration and equilibrium correction modeling, respectively. Hence, these relationships capture long-run (i.e., theory-driven) and short-run (i.e., data-driven) dynamics. In other words, the KGEMM represents theoretically coherent relationships, just as computable general equilibrium (CGE) or dynamic stochastic general equilibrium (DSGE) models do. Additionally, it represents deviations from the theory-dictated equilibrium relationships in the short-run, which are mainly data driven and modeled by equilibrium correction equations. This is the key advantage of KGEMM-type macroeconometric models over pure structural models, such as CGE and DSGE, and optimal growth models, as discussed by Nikas, Doukas, and Papandreou (2019, 37–38), inter alia.

Figure B1. Schematic illustration of KGEMM.



Source: Hasanov et al. (2022).

Appendix B. Additional features of the KGEMM

Because the long-run and short-run relationships among the variables are estimated using the cointegration and ECM frameworks, there are two versions of the model. The long-run version is based on the estimated cointegrated equations (e.g., like the macroeconometric models in Weyerstrass et al. [2018]; Khan and ud Din [2011]; Weyerstrass and Neck [2007]; Musila [2002]), whereas the short-run version is based on estimated ECM equations (e.g., Buenafe and Reyes [2001]; Dreger and Marcelinno 2007; Welfe [2013]).

We use the long-run version of the model for simulations, because our out-of-sample simulations span five years, and because of the discussion in Appendix A about endogeneity in Hasanov et al. (2022).[25] Note that Weyerstrass et al. (2018) and Weyerstrass and Neck (2007) for the Slovakian economy; Khan and ud Din (2011) for the Pakistani economy; Fair (1979, 1993) for the U.S. economy, Musila (2002) for the Malawian economy, Looney (1985) for the Iranian economy and Looney (1986, 1988, 1989) for the Saudi economy also used long-run versions of their macroeconometric models in their policy analyses and simulations. Detailed discussions of each version are available from the authors upon request.

Notes

Notes

About the Authors

Fakhri J. Hasanov

Fakhri Hasanov is a senior research fellow and leads the KAPSARC Global Energy Macroeconometric Model (KGEMM) project. He was previously an associate professor and director of the Center for Socio-Economic Research at Qafqaz University, Azerbaijan. He holds a Ph.D. in econometrics from Azerbaijan State University of Economics and completed his post-doctoral work and study at George Washington University. His research interests and experience span econometric modeling and forecasting, time series and panel data econometrics, building and application of macroeconometric models for policy analyses with a particular focus on countries rich in natural resources, energy economics and environmental economics.

Noha Abdel Razek

Dr. Noha Abdel Razek is an assistant professor in the Department of Economics at the University of Regina. Dr. Noha Razek received her Ph.D. in economics in 2012 from the University of Alberta. She has more than 15 years of research experience. Her research interests include international finance, energy economics, international energy policy and energy and the economy. She has held various positions in government, academia, and international research institutes in Canada and overseas. Before joining the University of Regina, Dr. Noha Razek was a senior research associate at KAPSARC. Previously, she was a post-doctoral fellow at the China Institute, a researcher at the School of Business at the University of Alberta and a Visiting Assistant Professor at the American University in Cairo. Her research has been published in high-quality peer-reviewed journals. She is a liaison for the American Economic Association's (AEA) Committee on the Status of Women in the Economics Profession (CSWEP).

About the Project

This study was part of the KGEMM Policy and Research Studies and KGEMM Model development projects.

The KGEMM Policy and Research Studies project produces policy and applied research studies that can provide Saudi Arabian decision-makers with a better understanding of domestic and international macroeconomic-energy relationships. Project research mainly employs the KGEMM, an energy-sector augmented general equilibrium macro-econometric model, as well as partial equilibrium frameworks.

The KGEMM Model development project extends, enhances and customizes the KGEMM's internal and international representations in line with the initiatives and targets of Saudi Vision 2030 and the requirements of the energy ecosystem entities. The goal of the project is to address policy options for the development of the Saudi economy. Its activities also include constructing small-scale models, tools, and dashboards.